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REMOTE SENSING REPORT, BALTIMORE HARBOR AND WICOMICO RIVER BASIN, MARYLAND

NATIONAL FIELD INVESTIGATIONS CENTER

MARCH 1974

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REMOTE SENSING REPORT

BALTIMORE HARBOR

WICOMICO RIVER BASIN

COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE

NATIONAL FIELD INVESTIGATIONS CENTER-DENVER
DENVER, COLORADO

MARCH 1974

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GLOSSARY OF TERMS

°C - Temperature in degrees Centigrade = 5/9 (°Farenheit -32)

cm - Length in centimeters = 0.3937 inches or 0.03281 feet

gal. - Volume in gallons = 3.785 liters

Hg - Mercury

km - Distance in kilometers = 0.621 miles

km^2 - Area in square kilometers = 100 hectares or 0.3861 square miles

m - Length in meters = 3.281 feet or 1.094 yards

m^2 - Area in square meters = 1.196 square yards

m^3/day - Flow rate in cubic meters per day = 0.000264 million gallons per day

m^3/sec - Flow rate in cubic meters per second = 22.8 million gallons per day = 35.3 cubic feet per second

mm - Length in millimeters = 0.1 centimeter

I. INTRODUCTION

An aerial remote sensing study of Baltimore Harbor and the Wicomico River Basin was conducted on 9 May 1973. This investigation was undertaken at the request of the Department of Natural Resources, State of Maryland.

The study encompassed the following areas:

a) The estuarine waters of the Patapsco River from the City of Baltimore, Maryland to the Chesapeake Bay. This area includes the Northwest Harbor, Middle Branch, Curtis Bay, and the lower reaches of Bear Creek and Old Road Bay near Sparrows Point.

b) The Wicomico River from State Highway 6 to the Potomac River including Chaptico Bay, the lower sections of Hayden Run, Allens Fresh, St. Clement Bay and Clement Creek.

The purpose of the Baltimore Harbor study was to document the presence of discharges of wastewater to the Harbor from municipal and industrial sources, storm drains, and other unidentifiable sources. Photographic and thermal infrared data were recorded during the day and thermal infrared data were recorded at night using sensors mounted in high performance reconnaissance aircraft. No ground truth was collected. All observed discharges were compared to known municipal and industrial wastewater discharges to identify locations of potential sources that had not filed for waste discharge permits. In addition, the relative magnitude, color, dispersion behavior and, in some cases, relative levels of concentrations of the detected discharges and resulting plumes were documented. Other indications of water quality degradation, such as oil slicks and algal blooms, were also documented. The thermal data for both day and night conditions were analyzed to provide relative isarthermal* data for the major discharges to define the dispersion patterns of the resulting thermal fields. The lack of ground truth precluded the assignment of actual temperatures to observed thermal fields.

The Wicomico River Basin study was undertaken to document the presence of surface and near-surface water on lands adjacent to this estuarine area and to identify paths of movement of such water from the land into the estuaries. Shellfish beds in the estuaries have been closed to commercial harvesting for several years due to the detection of excessive fecal coliform bacteria concentrations in the shellfish. Numerous hog farms and residences with individual sewage disposal systems in the areas adjacent to the estuaries are believed to be the sources of the bacterial contamination. The paths of water movement documented by the study are potential paths for movement of the bacteria from sources to shellfish beds. The Maryland Department of Natural Resources will use study data to trace the drainage connections from each hog feedlot to the estuaries.

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* Isarthermal is used to mean an area of the water surface displaying an essentially constant temperature as contrasted with isothermal which means a line of constant temperature.

II. SUMMARY AND CONCLUSIONS

BALTIMORE HARBOR

A total of 174 active wastewater discharges, storm drain discharges and indications of potential wastewater discharges were observed in the study area. Only 67 (38 percent) of these could be identified as wastewater discharges reported in Refuse Act Permit Program applications submitted to EPA in 1971. About 2,050 liters (540 gal.) of oil were recorded in numerous oil slicks with the largest amount observed in Northwest Harbor. Most of the Harbor waters were highly turbid, partially as a result of rainfall preceding the study. Storm drains discharging surface runoff probably account for some of the unknown discharges. Brown algal blooms were observed at various locations in the Harbor.

The Harbor was divided into five sub-areas to facilitate presentation of study results. Observations in each sub-area are summarized below.

Northwest Harbor (Area A)

Fifty-two actual or potential wastewater discharges and 4 indications of water quality degradation were observed in this area. Only 17 (33 percent) of the discharges could be identified with sources reported in permit applications. Oil slicks in Northwest Harbor contained an estimated 1,160 liters (300 gal.) of oil, about 56 percent of the total amount of oil detected in the entire Baltimore Harbor. The entire Northwest Harbor was turbid.

Middle Branch and Upper Inner Harbor (Area B)

Thirty-five discharges of wastewater or surface runoff from industrial facilities were recorded in this area. Thirteen (37 percent) of these corresponded to discharges reported in permit applications. Surface oil slicks in this area contained an estimated 530 liters (140 gal.) of oil, 26 percent of the total recorded. The influent from the Patapsco River was quite turbid and was cooler in temperature than the Inner Harbor.

Lower Inner Harbor and Curtis Bay (Area C)

Fifty-eight active wastewater discharges and seven indications of water quality degradation were observed in this large area of the Inner Harbor. Only 21 (36 percent) of the discharges were reported in permit applications. Oil slicks recorded in this area contained only 250 liters (65 gal.) of oil, about 12 percent of the total documented. The waters of Curtis Bay and lower Curtis Creek were dark brown while the Inner Harbor waters contained large areas of heavy turbidity.

Outer Harbor And Sparrows Point (Area D)

Twenty-eight actual or potential wastewater discharges and 5 other indications of water quality degradation were observed in the large Outer Harbor area. Fifteen (54 percent) of these were associated with sources reported in permit applications. Large amounts of brown algae were present in this area.

Upper Back River (Area E)

Only one wastewater discharge, originating from a municipal wastewater treatment plant, was recorded in this area. The River waters were highly turbid. No brown algae were observed.

WICOMICO RIVER

Numerous interconnections between estuarine waters and surface and near-surface waters on adjacent lands were documented. These interconnections could provide paths for water movement into the estuaries, thus creating potential means of transporting fecal coliform bacteria from hog farms and private residences to shellfish beds.

III. BACKGROUND INFORMATION

This study encompassed the estuarine waters of the Patapsco River (Baltimore Harbor) [Figure III-1] and the Wicomico River Basin [Figure III-2] in the State of Maryland. The two study areas are similar in climatic conditions and both are tributary to Chesapeake Bay. However, the two study areas have significant differences in physical, tidal, and hydrologic characteristics as discussed in the following sections.

BALTIMORE HARBOR

Modified by man to support a variety of industrial and shipping enterprises, Baltimore Harbor is a unique body of water. This harbor was instrumental in the development of Baltimore as the State's largest city (1973 population of 2,070,670), excellent port facilities, and an industrial center. The industial and suburban development of the metropolitan area followed the course of the Patapsco River upstream, becoming rural near the headwaters of the river.

The study area is located at the mouth of the Patapsco River and includes the estuarine waters from the City of Baltimore, Maryland to the Chesapeake Bay, as well as a portion of Back River, an adjacent tributary of Chesapeake Bay. Baltimore Harbor, also known as the Patapsco River estuary, is divided into two areas. That body of water lying west of the Outer Harbor Crossing, constructed between Sollers and Hawkins Point, is known as Inner Harbor, and the portion lying to the east of the bridge toward Chesapeake Bay is known as Outer Harbor.

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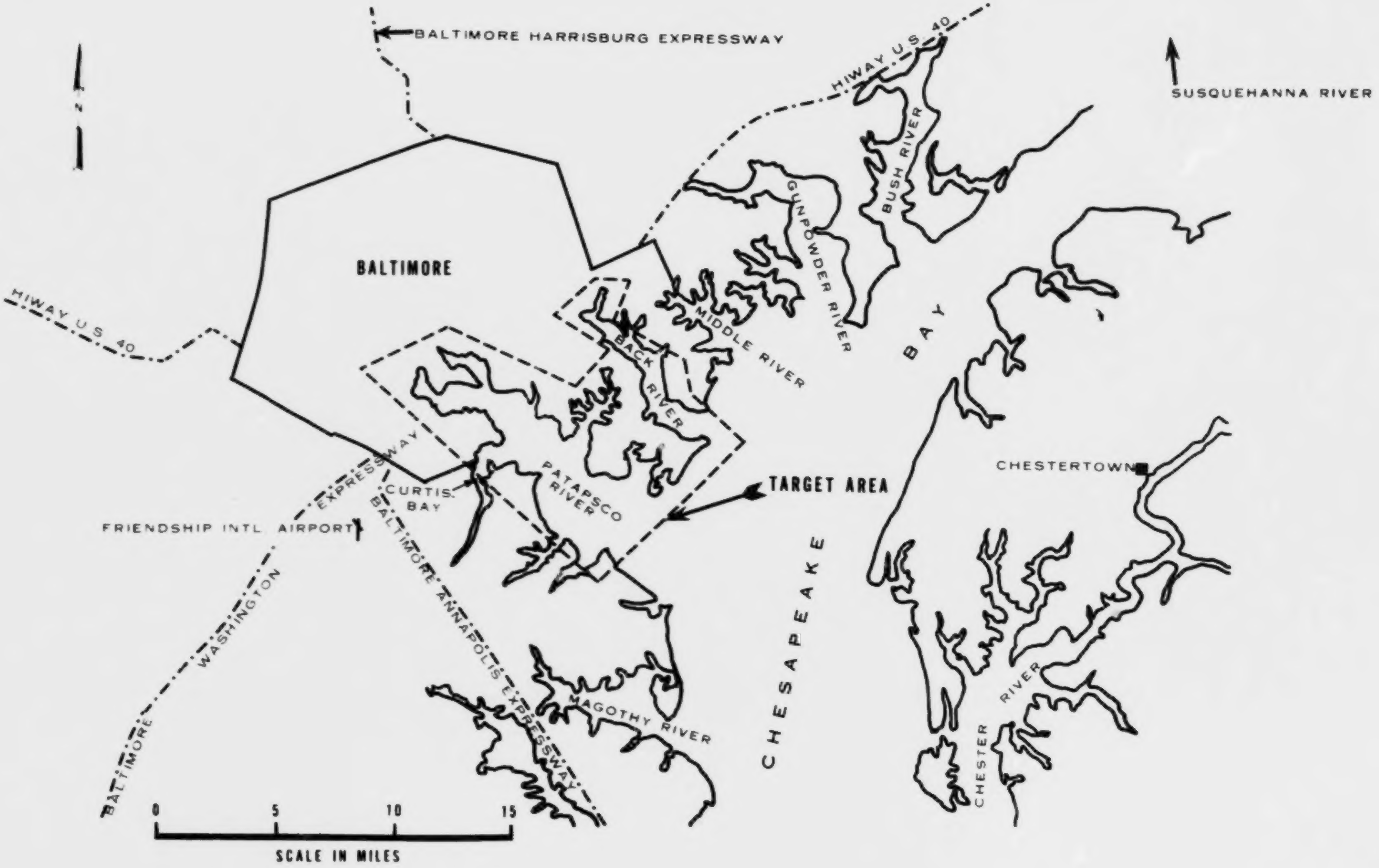

N
BALTIMORE HARRISBURG EXPRESSWAY
HIWAY U.S. 40
SUSQUEHANNA RIVER
BUSH RIVER
GUNPOWDER RIVER
BALTIMORE
HIWAY U.S. 40
MIDDLE RIVER
BACK RIVER
BAY
CHESTERTOWN
TARGET AREA
PATAPSCO RIVER
CURTIS BAY
EXPRESSWAY
FRIENDSHIP INTL. AIRPORT
BALTIMORE WASHINGTON
BALTIMORE ANNAPOLIS EXPRESSWAY
MAGOTHY RIVER
CHESAPEAKE
CHESTER RIVER
0
5
10
15
SCALE IN MILES

Figure iii-1. Location Map - Baltimore Harbor

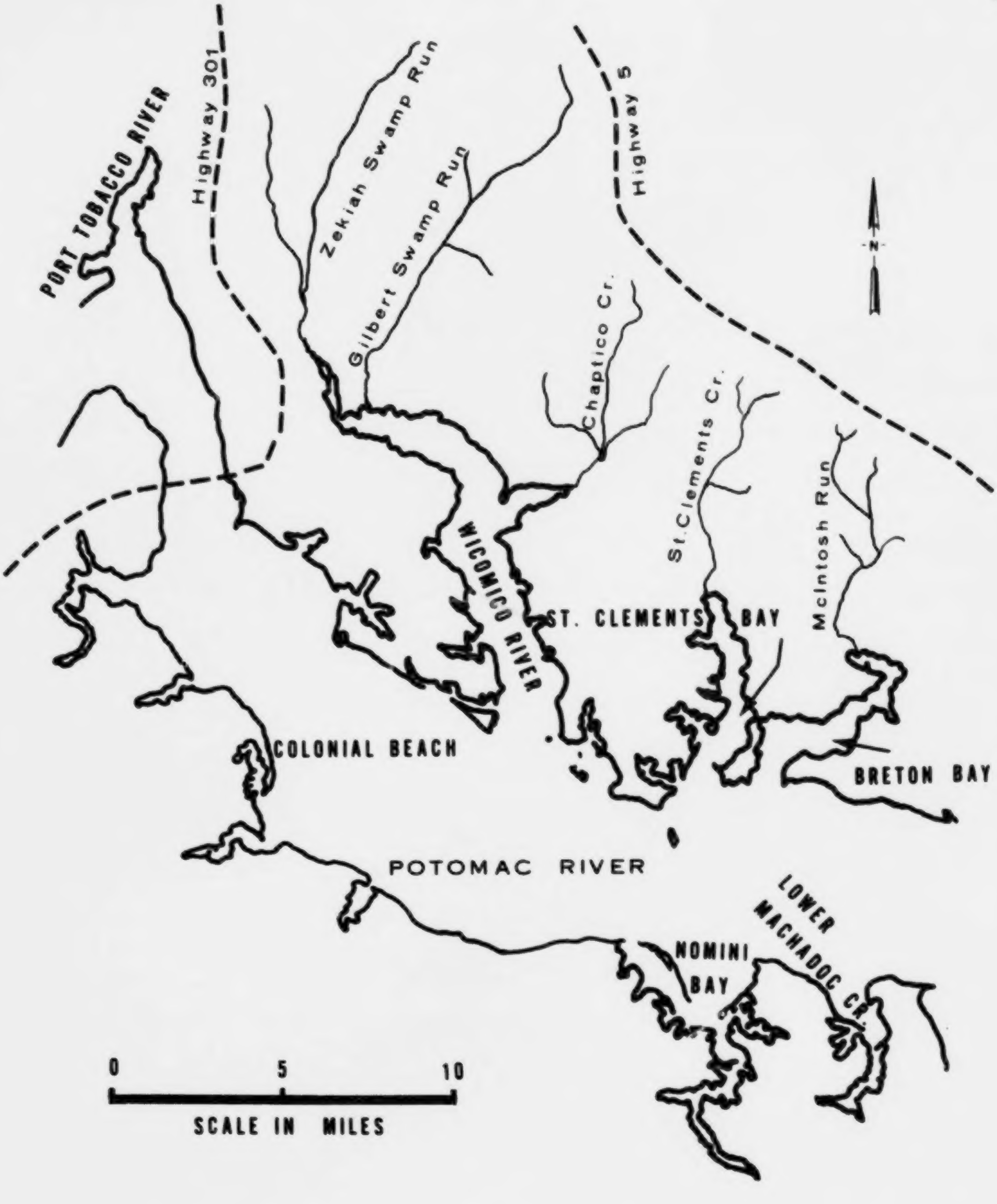

Highway 301
Zekiah Swamp Run
Gilbert Swamp Run
Highway 5
PORT TOBACCO RIVER
N
Chaptico Cr.
St. Clements Cr.
McIntosh Run
WICOMICO RIVER
ST. CLEMENTS BAY
COLONIAL BEACH
BRETON BAY
POTOMAC RIVER
LOWER MACHADOC CR.
NOMINI BAY
0
5
10
SCALE IN MILES

Figure III–2 Location Map Wicomico Basin

Tributary areas of interest in the Inner Harbor include Northwest Harbor, Middle Branch and Curtis Bay.

The Harbor extends southeasterly from downtown Baltimore 16 km (10 mi) to its point of entry into Chesapeake Bay where it is about 6.5 km (4.0 mi) wide. Within Inner Harbor the width varies between 2 and 4 km (1.2 to 2.5 mi). Few shallow (1 m) areas exist and more than 75 percent of the Harbor has a depth of 4 m (13 ft) or greater. Shipping channels are maintained at depths of 8 to 12 m (25 to 39 ft) or more through dredging operations.

The major stream entering Baltimore Harbor is the Patapsco River. Draining an area of over 770 km^2 (300 mi^2), the average river discharge for the past two decades has been about 4 m^3/sec (140 cfs). The river flow has been regulated since 1954 by Liberty Reservoir which is used by the City of Baltimore as a water supply. Prior to 1954 the average river flow into the Harbor was 10 m^3/sec (360 cfs). Gwynns Falls and Jones Falls, tributaries to the Harbor area of the Patapsco River, each have an average flow of about 1 m^3/sec (35 cfs). The remaining tributaries to the Harbor are small and would have an average combined flow of about 1 m^3/sec. Maximum streamflow entering the Harbor has reached 3,200 m^3/sec; and at times during mid and late summer the total flow into the Harbor has been less than 0.6 m^3/sec.

In addition to Baltimore Harbor proper, the study area also includes the lower 12 km (7.5 mi) of the Back River, a shallow body of water just north of the Patapsco estuary. This reach of river has a width averaging about 1.3 km (0.8 mi). The embayment reaches depths of 8 m (26 ft) just prior to entry into the Chesapeake Bay, but averages about 2.5 m (8 ft). The total combined inflow into the embayment area of the Back River averages about 0.5 m^3/sec (18 cfs).

Owing to the proximity to Baltimore, some industrial growth has occurred at the end of the Back River embayment area, but most development has come in the form of suburbs. As a result, one of the major water uses in the area is that of waterfront recreation.

Due to the distance from the Atlantic Ocean, tidal effects are dampened considerably by the time they reach Baltimore Harbor. Tides inside the Harbor produce currents that are too weak and variable to be predicted. Tides are semidiurnal with a mean and spring tide range of 0.34 m (1.1 ft) and 0.40 m (1.3 ft), respectively. Lag times for tidal changes are small with a high water and low water difference through the Harbor itself of only 24 and 22 minutes, respectively. During periods of low river flow, a stagnated water condition may exist within Inner Harbor.

As determined from climatalogical data stations located at Baltimore, the average annual precipitation in the Baltimore Harbor area is 1,100 mm (43 in.); average snowfall is 450 mm (18 in.) per year; and the average annual air temperature is 14°C (57°F). Average monthly air temperatures range from 2°C (35°F) in January to 26°C (78°F) in July with extremes ranging from -22°C (-7°F) to 42°C (107°F). High humidity (generally exceeding 60 percent) occurs most of the year due to close proximity to open water areas.

Baltimore Harbor presents a special problem in water quality enforcement. Within the Baltimore metropolitan area and surrounding areas of Baltimore and Anne Arundel counties, about 1,250 manufacturing firms exist. Many of these firms discharge industrial wastes directly to the Harbor or to storm drains discharging to the Harbor. Identification of those industrial sources that are not connected to municipal sewerage systems and that have not applied for a NPDES permit is a difficult task complicated by the presence of numerous known waste discharges. In addition to industrial sources, wastewaters and pollutants are discharged to the Harbor from the City of Baltimore Patapsco Sewage Treatment Plant, city storm drains, ships and boats, small tributary streams, and spills of oil and other deleterious materials.

WICOMICO RIVER

The Wicomico River and St. Clement Creek/Bay study area is located in southern Maryland about 65 km (40 mi) south and a little east of Washington, D.C. The area is a low, hilly, heavily vegetated, rural area with numerous farms and homesteads scattered throughout. Production of livestock and raising cash and truck crops provide the major economic activities of the area.

Both the Wicomico River and St. Clement Creek discharge to the Potomac River about 50 km (31 mi) above its confluence with Chesapeake Bay. Both embayments have shellfish beds which have been closed to commercial fishing as a result of the detection of excessive concentrations of fecal coliform bacteria in the shellfish. The source of the bacterial contamination is thought to be various farms engaged in hog production activities on lands adjacent to water bodies within the area. This reach of the Potomac River links the Washington, D.C. metropolitan area with other shipping centers of the East Coast.

The streams, water bodies, and adjacent land areas that were considered in the study area include: Pope Creek and adjacent lands (3 to 4 km in length); Zekiah Swamp Run and Allens Fresh Run with lands adjacent to the east and west (11 to 12 km in length); Wicomico River and adjacent lands on the east and north shores (20 km in length); Chaptico Bay/Creek and adjacent lands (8 to 10 km); and St. Clements Bay/Creek with lands adjacent on the east and west (12 to 14 km in length).

Regular monitoring of stream flows occurs only on Chaptico Creek and St. Clements Creek which have average annual flows of 0.3 m^3/sec (10 cfs) and 0.6 m^3/sec (20 cfs), respectively. Maximum yearly flows generally occur during early spring months with low flow periods during late summer and early fall months. Chaptico and St. Clements Creeks have recorded flow ranges from 0 to 220 m^3/sec and 0 to 125 m^3/sec, respectively.

From miscellaneous measurements collected by the Geological Survey, it is estimated that the average annual stream flows into Wicomico River (including Allens Fresh, Gilbert Swamp Run, and Chaptico Creek) total about 2.0 m^3/sec (70 cfs). Minimum and maximum flows range between about 0.3 m^3/sec (10 cfs) to 425 m^3/sec (15,000 cfs), respectively. The stream flow of Pope Creek is estimated to be 0.03 m^3/sec (1 cfs).

Within both the Wicomico River and St. Clements Bay the tides are semi-diurnal. High and low water time differences from the reference station at Washington, D.C. vary between about 6 and 6-1/2 hrs. Within Wicomico River the lag time for tidal changes is small with a high and low water difference through the embayment of 18 and 23 minutes, respectively. Mean and spring tide ranges are 0.6 m (1.9 ft) and 0.7 m (2.2 ft), respectively, with fluctuations throughout the embayment about 0.12 m (0.4 ft). At the entrance to the Wicomico River embayment, the maximum flood and ebb tide velocities average 0.9 km/hr (0.5 knots) at time intervals of 3-1/2 hrs. At the entrance to St. Clements Bay, tidal currents are too weak and variable to be predicted. At Shipping Pt. in St. Clements Bay, the mean and spring tidal ranges are 0.55 m (1.8 ft) and 0.65 m (2.1 ft), respectively.

As determined from the climatalogical stations located at Charlotte Hall and Leonardtown, Maryland, the average annual precipitation in the basin is approximately 1,070 mm (42 in); the average annual air temperature in the Wicomico River basin is 14°C (57°F). Average monthly air temperatures range from 3°C (37°F) in January to 26°C (78°F) in July with extremes from -22°C (-8°F) to 38°C (101°F). High humidity occurs most of the year due to vast marsh and open water areas.

IV. STUDY TECHNIQUES

AIRCRAFT AND FLIGHT DATA

Two high-performance aircraft, specifically designed and equipped for aerial reconnaissance work, were used to carry out this remote sensing mission. One aircraft (A) was used for both the day and night flights over the Baltimore Harbor study area while the other aircraft (B) was used for the Wicomico River study area.

The flight parameter data that specify the values of the aerial reconnaissance variables are summarized in Table IV-1. These variables are important at the time the mission is flown and during the analysis of the airborne data. With rare exception, the airspeed variations are automatically processed in the aircraft computer system and, combined with aircraft altitude, used to calculate the amount of photographic stero overlap.

SENSOR DATA

Cameras

The sensors carried on board each aircraft were KS-87B aerial framing cameras equipped with 152 mm (6 in.) focal length lens assemblies and an infrared line scanner (IRLS). Aircraft A used three cameras while aircraft B used only one camera. The sensors were mounted in the aircraft in their respective vertical positions as shown in Figure IV-1.

The viewing angle of the KS-87B framing cameras was 41° centered about the aircrafts nadir as shown in Figure IV-2. A diagram of a typical framing camera is shown in Figure IV-3.

TABLE IV-1

FLIGHT PARAMETER DATA

Parameter	Location		
	Baltimore Harbor		Wicomico River
Date of Flight	9 May 1973		9 May 1973
Time of Flight (Eastern Daylight Time)	1350 to 1530 2030 to 2130		1400 to 1530
Air Speed	666 km/hr (360 knots)		666 km/hr (360 knots)
Altitude Above Ground Level	762 m (2500 ft)	-Day-	1220 m (4000 ft)
	792 to 870 m (2600 to 2850 ft)	-Night-	No Flight
Sensors	All	-Day-	1 Camera, IRLS
	IRLS[a]	-Night-	No Flight

---

[a] Infrared Line Scanner.

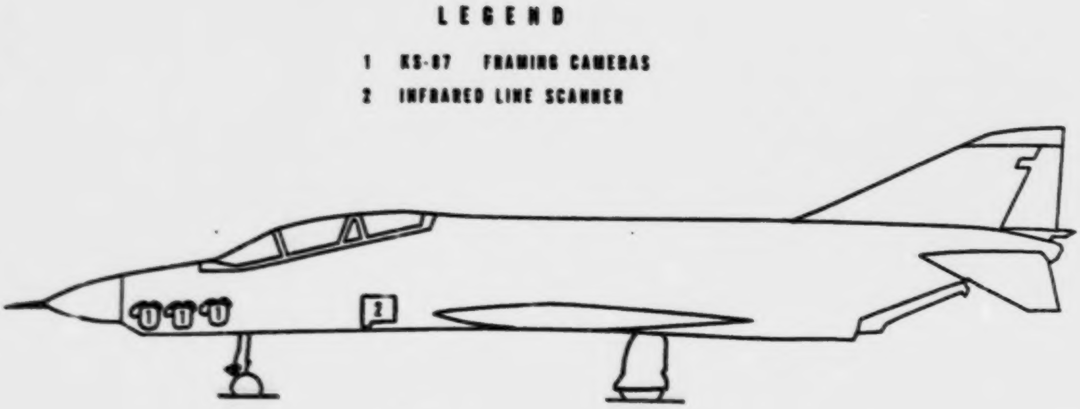

LEGEND
1 KS-87 FRAMING CAMERAS
2 INFRARED LINE SCANNER
1
1
1
2

Figure IV-1. Aircraft Sensor Locations

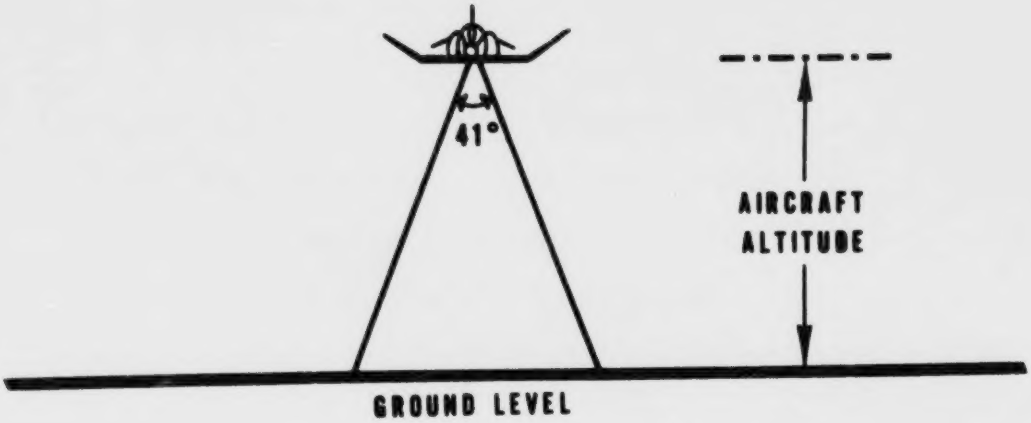
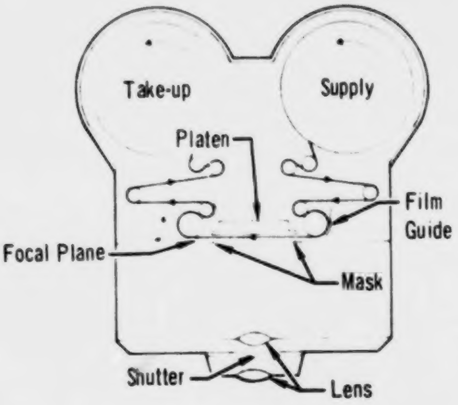

41°
AIRCRAFT
ALTITUDE
GROUND LEVEL

Figure IV-2. Viewing Angle of Framing Camera


Take-up
Supply
Platen
Film Guide
Focal Plane
Mask
Shutter
Lens

Film Advances Frame by Frame

Figure IV-3. Framing Camera

Films and Filters

The framing cameras on Aircraft A were up-loaded with different film and optical filter combinations as follows:

Camera Station 1--Kodak S0-397 Aerographic Ektachrome Film with a Wratten HF-3/HF-5 gelatin optical filter combination. This film is 127 mm (5 in.) wide providing a true color transparency measuring 114 mm x 114 mm (4.5 in. x 4.5 in.). The filter combination prohibits ultraviolet light from reaching the film, thus eliminating the effects of atmospheric haze.

Camera Station 2--Kodak 2402 plus-X Aerographic Film (127 mm wide) with a Wratten 39 glass optical filter. This film-filter combination provides a black-white negative having been exposed to near-ultraviolet and deep-blue optical energy. This sensor was primarily used for the detection of oil slicks.

Camera Station 3--Kodak 2443 Aerochrome Infrared Film with a Wratten 16 gelatin optical filter. This film is also 127 mm wide resulting in color transparencies measuring about 114 mm x 114 mm.

The Wratten 16 filter (deep orange in color) transmits a portion of the visible optical spectrum (i.e., deep green, yellow, orange, and red) along with the near-infrared energy from 7.0 to 1.0 microns. The film presents a modified color or false color rendition in the processed transparency unlike the more familiar true color films. It has an emulsion layer that is sensitive to the near-infrared in addition to the red and green layers, whereas the true color ektachrome films have red, green, and blue sensitive layers. (Every color film has various combinations of red, green and blue dyes similar to the red, green and blue dots on the front of a color television picture tube.) The modified or false color rendition comes into play when the exposed image on the infrared film is processed.

In the finished transparency, the scene objects (trees, plants, algae) producing infrared radiation appear red while red and green objects produce green and blue images, respectively. The most important asset of this film is its capability of recording the presence of various levels of chlorophyll in terrestrial and aquatic plant growth. The leaves on a healthy tree will record as a bright red image rather than the usual green. Unhealthy foliage will approach a brownish red color. The orange filter is used to keep all blue light, which would cause an unbalance in the normal red, green, and blue color balance, from reaching the film.

Aircraft B was also configured as shown in Figure IV-1. Only one camera was used for the Wicomico River area. It was up-loaded with Kodak 2443 Aerochrome Infrared Film with a Wratten 16 gelatin optical filter. This film-filter combination greatly eases the task of locating surface water due to its false color rendition (foliage is shown as red and water is blue).

Infrared Line Scanner

Each aircraft was equipped with an AN/AAS-10 Infrared Line Scanner (IRLS) which is located on the underside of the aircraft as shown in

Figure IV-1. While in operation it images an area along the flight path of the aircraft. The width of the image area is dependent upon aircraft altitude and is encompassed by a 120° field-of-view in crosstrack or perpendicular to the flight path as shown in Figure IV-4.

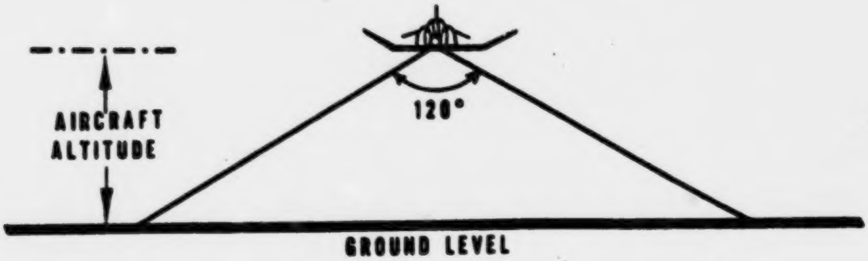

AIRCRAFT
ALTITUDE
120°
GROUND LEVEL

Figure IV-4. Field of View of IRLS

An IRLS converts variations in infrared energy emissions from objects of different temperatures into a thermal map. The three basic parts of an IRLS are the scanner optics, a detector array, and a recording unit. The scanner optics collect the infrared emissions from ground and water areas and focus them on the detectors as shown in Figure IV-5.

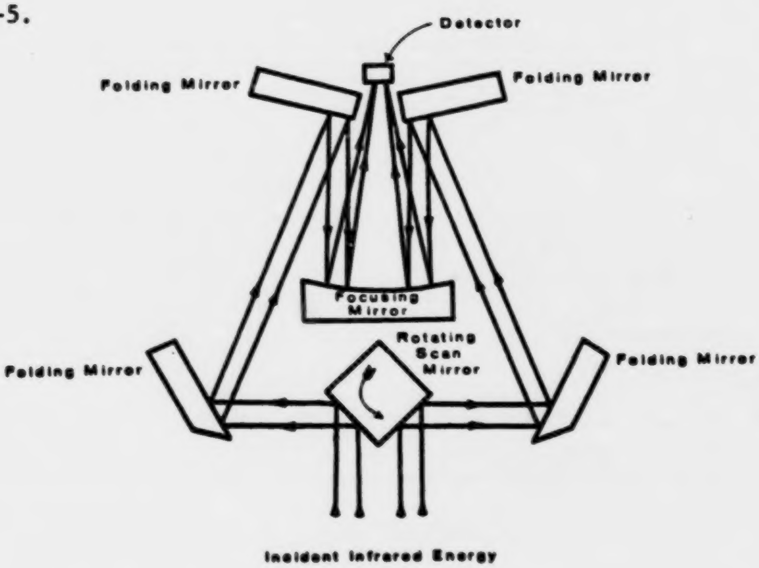

Detector
Folding Mirror
Folding Mirror
Focusing Mirror
Rotating Scan Mirror
Folding Mirror
Folding Mirror
Incident Infrared Energy

Figure IV-5. IRLS Optical Collection System

The detectors, cryogenically cooled to 26° Kelvin, convert the infrared energy collected by the scanner optics into an electronic signal. This signal is processed electronically and subsequently transformed into visible light through a cathode ray tube. This light is then recorded on ordinary RAR black-and-white film 126 mm (5 in.) wide. The recorded thermal map is 100 mm (4 in.) wide and its length depends upon the length of a particular line of flight being imaged.

The IRLS has a sensitivity bandwidth from 8 to 14 microns, the so-called thermal band of the electromagnetic spectrum. Applying Wien's Displacement Law, this represents a temperature band from -66°C to 89°C. The system has an instantaneous field-of-view of 1 milliradian by 1 milliradian. The total field of view is achieved by the rotating mirror in the optical collection system, which is 120° by 1 milliradian. The measured noise equivalent temperature (NET) of the IRLS is 0.32°C with 100 percent probability of target detection. This represents an effective measurement of the temperature resolution of the system.

The spectral sensitivity data for each film and the optical filter transmittance curves are shown in Appendix A. Information regarding the development process for each type of film is provided in Appendix B. Appendix C contains information pertinent to aerial sensors in respect to focal length, angle of view, and the effects of focal length and altitude on scale and ground coverage.

GROUND TRUTH

No ground truth was obtained at the time of flight.

DATA INTERPRETATION AND ANALYSIS

All data interpretations and analyses were carried out on the original IRLS films rather than photographic prints of duplicated transparancies because an additional image generation would create image degradation in scale and color balance. The original films are the following: true color transparencies, false color infrared transparencies, black-and-white ultraviolet negative and the IRLS thermal image black-and-white negative.

Standard image analysis techniques were employed in the reduction of the aerial reconnaissance data which include the physical measurements of distances and areas, and stereoscopic analysis of areas displaying topographic gradients on land and in the water.

The reduced data were subsequently plotted on U. S. Geologic Survey 7.5 minute topographic maps (scale 1:24,000) and U. S. Coast and Geodetic Survey Nautical Charts (Scale 1:15,000). Scale is shown on each photograph or thermal map in this report. To evaluate scale consistency, the map scales were compared to the imagery empirical scales derived from the optical focal length of each sensor and the altitude of the aircraft above water level. Appendix C contains further information regarding the effects of aircraft altitude upon image scale.

In the black-and-white IRLS film, temperature levels are represented by various shades of gray in the negative format or rendition. Areas of low density (clear film) represent cooler temperatures, and as the temperature of a particular target becomes warmer the density of gray in the film also increases. Positive prints presented in this report reflect the reverse of the negative film. Cool areas are dark while the warm areas are light gray.

A Spatial Data 704 Image Analyzer was used to convert the infrared images into isarthermal maps. Isarthermal maps deliniate areas with the same temperature (isartherms). The Image Analyzer uses a technique called density slicing to divide the density range on a given infrared image into 12 increments. Each increment thus represents a particular density of gray on the image and a narrow temperature range closely approximating an isartherm. The density value of each increment is accurate to within 0.03 density units over a range of 0 to 2 (density). Each density increment is displayed on the Image Analyzer screen in a particular color. Each isarthermal map was prepared by tracing directly from the color rendition on the Analyzer display screen.

An important factor must be mentioned at this point. The IRLS will only record water surface temperatures since water is opaque in this region of the infrared spectrum. The maximum depth penetration in either fresh or salt water is 0.01 cm. Therefore, a submerged thermal discharge can be detected from an aircraft with an IRLS only if the warm wastewater reaches the surface of the receiving body of water. The isothermal maps developed by this study thus represent surface temperatures only and may not necessarily reflect subsurface temperature distributions.

ERROR ANALYSIS

Limitations can be placed on the accuracy or uncertainty of the film analysis measurements carried out on the photographic and thermal data. Measurements for linear distance and surface area were made with scaling instruments and light table microscopes.

The uncertainty for linear distance (ΔLD) is:

$$\Delta LD = \pm 2 \times 10^{-4} \times \text{photographic scale (meters)} \qquad (1)$$

The photographic scale for Baltimore Harbor was 1:5,000. The value for $\Delta LD = (\pm 2 \times 10^{-4} \times 5{,}000)$ meters = ± 1 meter. A distance X, measured on the original photographic film, is accurate to within ± 1 meter.

The uncertainty for the surface area (ΔSA) is (rectangular):

$$\Delta SA = + \Delta LD\ (\pm X \pm Y) \qquad (2)$$

For Baltimore Harbor $\Delta SA = + (\pm X \pm Y)$ meter^2, (ΔLD = 1 meter).

For example, a rectangular area whose dimentions were X ± 1 meter and Y ± 1 meter, would have the value $[XY + (\pm X \pm Y)]$ meters^2.

The uncertainty in the IRLS is the measured system noise equivalent temperature which is ± 0.32°C. Since no ground truth was taken at the time of flight, no terrestrial instrumentation uncertainty has entered into the analysis picture.

No atmospheric corrections were applied to the reconnaissance data under the assumption that the atmospheric effect was constant through the air column between the aircraft and the water during the short duration of each phase of the mission. For the most part, the data was used for qualitative analysis only owing to the lack of ground truth.

V. RESULTS AND EVALUATION OF DATA ANALYSIS BALTIMORE HARBOR

This section presents the results of the analysis of the photographic and thermal infrared data obtained by day and night aerial reconnaissance on 9 May 1973. Tidal and weather conditions existing at the time of flight are summarized. Waste source data as reported in Refuse Act Permit Program (RAPP) applications are also presented. Observed waste discharges and thermal plumes are evaluated with respect to the reported magnitude and characteristics of known waste discharges as well as with regard to tidal and weather conditions. Other observed indications of potential waste discharges or water quality degradation such as outfalls, foam, oil slicks, algal growths, and significant changes in water color are also discussed.

Each significant observation of a known waste discharge, potential discharge, or indication of water quality degradation is assigned an identifying number. These numbers are overprinted in red on segments of nautical charts to facilitate location on the ground. Where necessary to show small details, sketch maps prepared by tracing the aerial photographs are presented. The extent and relative magnitude of significant thermal plumes are defined by thermal maps and/or isarthermal sketches prepared as discussed in Section IV. The lack of ground truth precluded definition of actual thermal plume temperatures. The identifying numbers are also used to key detailed discussions in the text to map locations. Data recorded during day and night flights are appropriately identified.

To facilitate presentation of the data, the study area has been divided into five sub-areas as shown in Figure V-1. Area A encompasses the Northwest Harbor (Northwest Branch). Area B includes the Middle Branch and the central portion of the Inner Harbor between the Middle Branch and the Harbor Tunnel. Included in Area C are Curtis Bay, Curtis Creek, and the remainder of the Inner Harbor (Harbor Tunnel to Outer Harbor Crossing near Ft. Carroll). Area D encompasses the Outer Harbor, and a portion of the Back River comprises Area E. These five areas are discussed separately in following sections.

ENVIRONMENTAL CONDITIONS AT TIME OF FLIGHT

Weather conditions for the Baltimore Harbor area for the period 1 to 9 May 1973 are summarized in Table V-1. These conditons were observed at Friendship International Airport located about 11 km (7 mi) southwest of the Harbor.

During the 37-hour period preceeding the day flight a total of 8.13 mm (0.32 in.) of rain had fallen, of which only 1.50 mm (0.06 in.) had fallen during the early morning hours on the day of the flights. This low rainfall amount coupled with the lack of significant antecedent precipitation would indicate that surface runoff during the day flight was minimal. Soil characteristics, however, would show high turbidity and color in the runoff that did occur.

At the time of the day flight, the target area had scattered clouds at an altitude of 1,280 m (4,200 ft) while during the night flight the sky was virtually clear. Visibility was greater than 13 km (8 mi).

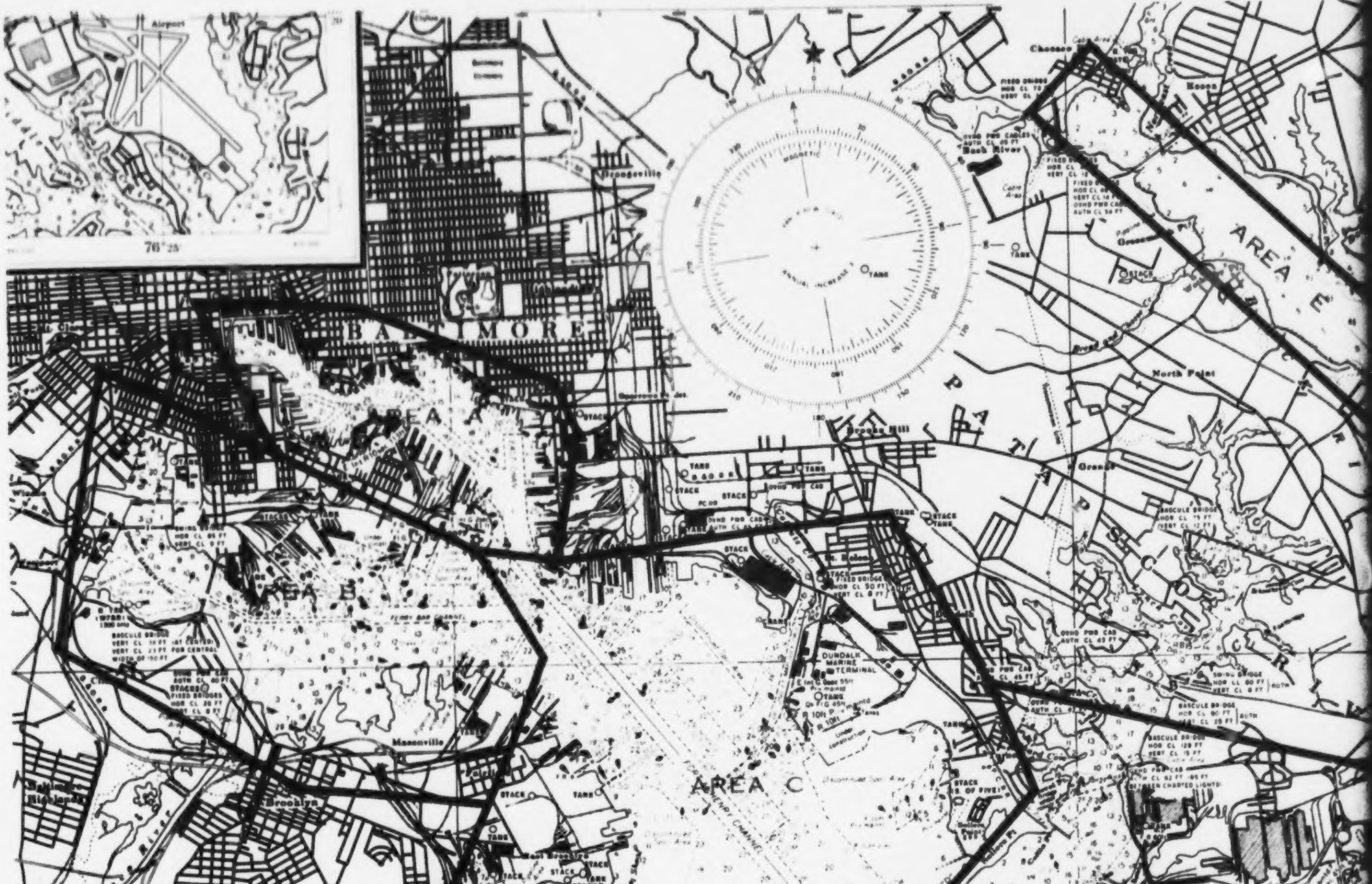

BALTIMORE
AREA A
AREA B
AREA C
AREA E
PATAPSCO RIVER
MARLEY NECK
Brooklyn
Curtis Bay
Fishing Pt
Masonville
Dundalk Marine Terminal
North Point
Sparrows Point
Brewerton Angle
Fort Carroll
Pumphrey
Baltimore Highlands
76°35'
MAGNETIC
ANNUAL INCREASE
NOTE B
Radar reflectors are not shown on this chart above Brewerton Angle. See Chart 545
VHF WEATHER BROADCASTS FOR MARINERS
FM Stations with a range of approximately 40 miles are in continuous operation 24 hours daily broadcasting weather warnings, forecasts and reports from the NATIONAL WEATHER SERVICE Office as follows
Washington D.C. KHB 36 162.550 MHz
NOTE C
CAUTION

Figure V-1 Sub-Area Map of Balti

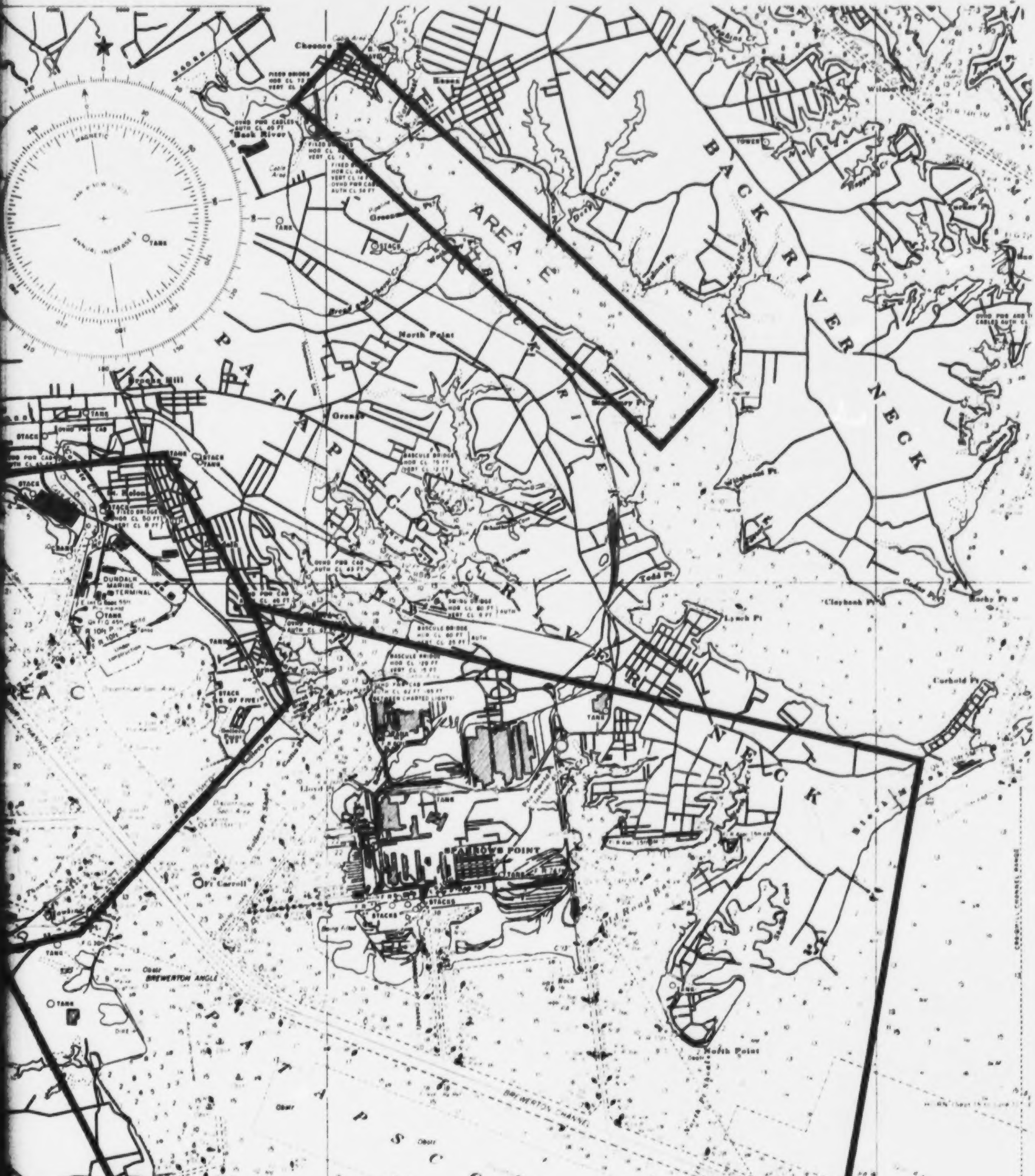

AREA E
BACK RIVER NECK
BACK RIVER
PATAPSCO RIVER
PATAPSCO NECK
AREA C
SPARROWS POINT
North Point
Back River
Sollers Pt
Ft Carroll
BREWERTON ANGLE
CUTOFF ANGLE
DUNDALK MARINE TERMINAL
Todd Pt
Lynch Pt
Claybank Pt
Cedar Pt
Rocky Pt
Wilson Pt
Millers Is
Coxeys Pt

Figure V-1 Sub-Area Map of Baltimore Harbor

TABLE V-1

WEATHER CONDITIONS, BALTIMORE HARBOR[a]
1 TO 9 MAY 1973

Date	Maximum Air Temperature Time[b]	(°C)	(°F)	Minimum Air Temperature Time	(°C)	(°F)	Relative Humidity[c] (percent)	Wind[c] Direction	Speed (km/hr)	(mph)	Barometric Pressure[c] (in. Hg)	Precipitation[d] (mm)	(in.)
May 1	1700	23	74	0300	8	46	53	135°	16	10	30.05	0	0
2	1500	29	84	0500	14	57	52	155°	23	14	29.96	0	0
3	0900	21	69	2400	12	54	84	245°	14	9	29.6	3.6	0.14
4	1000	13	56	0600	7	44	53	290°	29	18	29.97	0	0
5	1700	17	62	0400	4	39	37	290°	23	14	29.94	0	0
6	1500	21	70	0500	6	42	33	290°	23	14	30.08	0	0
7	1400	23	74	0255	7	44	37	110°	24	15	29.96	0	0
8	1400	19	66	0500	12	54	72	135°	26	16	29.66	6.6	0.26
9	1500	26	78	2400	14	57	60	315°	23	14	29.66	1.5	0.06
CONDITIONS DURING 9 MAY 1973 FLIGHTS													
Day Flight	1300[e]	23	74	-	-	-	60	315°	23	14	29.66	-	-
Night Flight	2000[e]	19	67	-	-	-	59						
	2100[e]	17	63	-	-	-	65	270°	6-8	4-5	29.87	-	-
	2200[e]	16	60	-	-	-	72						

[a] Weather observations were made at Friendship Airport, Baltimore, Maryland, located about 11 km (7 mi) south of Baltimore Harbor.
[b] Eastern Standard Time.
[c] Daily observations made at 1300 hours.
[d] Precipitation occurring during a 24-hour period ending at 1300 hours.
[e] Time of observation of current air temperature, relative humidity, wind speed and direction, and barometric pressure.

The wind at midday was blowing from the northwest at 23 km/hr (14 mph). In the evening it had shifted to the west and dropped to 6 to 8 km/hr (4 to 5 mph).

Predicated tidal conditions for several locations in Baltimore Harbor are shown in Table V-2. Prevailing weather conditions and the low tide range in the Harbor would indicate that actual tide conditions closely approximated predicted levels. The day mission was carried out during the ebb tide phase between high-high tide and low-low tide, while the night mission was conducted during a minor flood tide phase between low-low tide and the low-high tide occurring early on 10 May 1973.

NORTHWEST HARBOR (AREA A)

Northwest Harbor (also known as Northwest Branch) is the northernmost arm of the Inner Harbor [Figure V-1]. It extends about 5 km (3 mi) from Fort McHenry northwestward to the Basin located adjacent to downtown Baltimore [see Figure V-2, a foldout located at the end of the Area A description, for more detail]. The Harbor is relatively deep with navigation channels dredged to depths of 8 to 11 m (25 to 35 ft). The shoreline consists almost entirely of piers and docks. This area is the most heavily developed portion of Baltimore Harbor.

Jones Falls, a small stream, enters Northwest Harbor from the north about 0.8 km (0.5 mi) to the east of its western terminus. The small streamflow from Jones Falls coupled with urban runoff, industrial waste discharges and tidal interchange introduce relatively minor volumes of fresh inflow into Northwest Harbor. Water movements within the Harbor are thus relatively limited.

TABLE V-2

TIDAL CONDITIONS, BALTIMORE HARBOR
9 AND 10 MAY 1973

Date	Time[a]	Tide Height (Meters)	Tide Height (Feet)	Tide
		Fort McHenry		
May 9	0007	0.30	1.0	Low High
9	0556	0.06	0.2	High Low
9	1225	0.40	1.3	High High
9	1900	0.03	0.1	Low Low
10	0114	0.34	1.1	Low High
		Fells Point (Northwest Harbor)		
9	0013	0.33	1.1	Low High
9	0602	0.06	0.2	High Low
9	1230	0.43	1.4	High High
9	1906	0.03	0.1	Low Low
10	0119	0.37	1.2	Low High
		Middle Branch		
9	0029	0.27	0.9	Low High
9	0618	0.06	0.02	High Low
9	1247	0.37	1.2	High High
9	1918	0.03	0.1	Low Low
10	0136	0.30	1.0	Low High
		North Point (near Sparrows Point)		
9	0005	0.27	0.9	Low High
9	0552	0.06	0.2	High Low
9	1223	0.37	1.2	High High
9	1856	0.03	0.1	Low Low
10	0112	0.30	1.0	Low High

---

[a] Eastern Standard Time.

General Observations

The general color characteristics of the surface waters of Northwest Harbor, as recorded by true color photography on 9 May 1973, are shown in Figure V-2. The entire Harbor area was turbid, probably reflecting the effects of urban runoff from light rains on 8 and 9 May. Heavy turbidity (yellow-brown) was present from the Basin downstream decreasing to moderate turbidity (yellow-gray) in the Turning Basin off Fells Point. The heavy turbidity near the Basin could have resulted from the Jones Falls inflow. From Fells Point to the green demarcation line near the intersection of the East and West Channels, the water became dark brown. The water on the south side of the green line was yellow-gray in color and quite turbid. The color boundary at the green line was quite pronounced, probably a result of tidal phasing. An oil slick containing about 60 liters (16 gal.) of refined oil was observed near the intersection of the East and West Channels.

Specific Observations

Identifying numbers for specific observations are overprinted in red on Figure V-2, a section of U. S. Coast and Geodetic Survey Nautical Chart 545 (Scale 1:24,000).

A-1 (Day)--Two sunken ship hulls were covered with heavy growths of brown algae.

A-2 (Day)--This water surface area was heavily covered with brown algae (true color representation).

A-3 (Day)--An oil slick, containing about 40 liters (10 gal.) of refined oil, was located at this position. No discharge was observed.

A-4 (Day)--These three areas were heavily covered with brown algae.

A-5 (Day)--The water in this dock area was gray-brown in color and was dispersing slowly into the Harbor waters.

A-6 (Day)--Shore wash was present adjacent to a small tank farm resulting in a yellow-gray discoloration in the immediate area of the Harbor waters. There was no sign of a discharge at the time of flight.

A-7 (Day)--A structure that resembled an outfall structure was located in the corner of this dock area. There was minor foaming action around it. This particular area is within the Proctor and Gamble Manufacturing Company facility. Two outfalls discharging cooling water and surface runoff averaging 1,140 m^3/day (0.3 mgd) are reported in this area, however no thermal patterns were recorded.

A-8 (Night)--A thermal discharge, originating within the Proctor and Gamble facility on Locust Point, was recorded at this location. A cooling water discharge averaging 19,700 m^3/day (5.2 mgd) is reported here. An enlarged view of the thermal field recorded by the IRLS is shown in Figure V-3. Note that this is a positive print of the IRLS negative and that light areas are warmer than dark areas. An Isarthermal map [Figure V-4] of the thermal field was prepared using the techniques discussed in Section IV. The numbers assigned to the different areas represent temperature increments with No. 1 being the warmest and No. 7 the coolest. The absence of ground truth precluded the assignment of actual temperatures to each area. The temperature difference between the plume at the discharge point (No. 4) and the ambient or background Harbor water (No. 7)

4

Reproduced from best available copy.

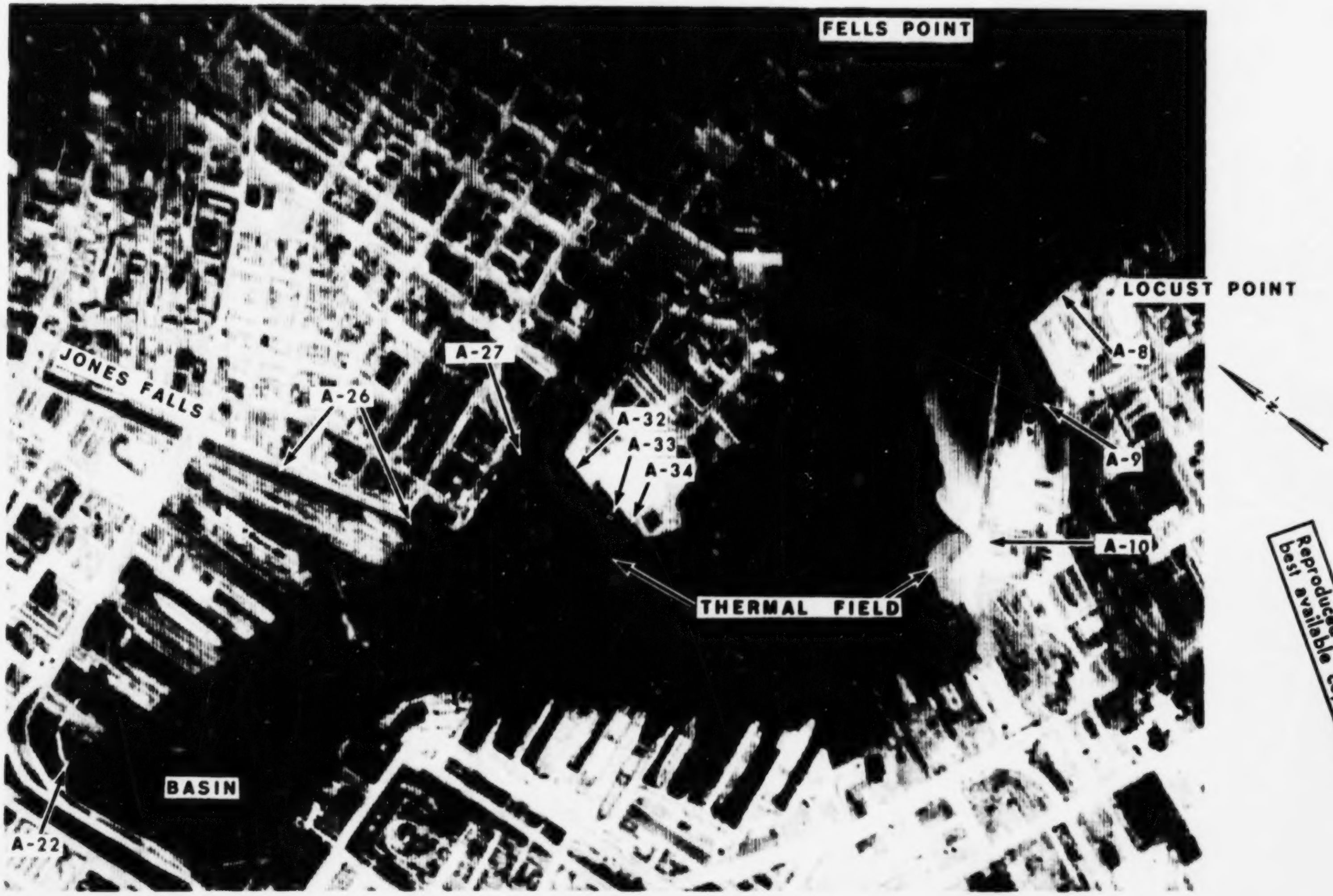

FELLS POINT
LOCUST POINT
A-8
A-9
A-10
JONES FALLS
A-27
A-26
A-32
A-33
A-34
THERMAL FIELD
BASIN
A-22
N

Figure V-3 Enlarged Thermal Map (Night) - Northwest Harbor

was three increments representing an estimated differential of about 1 to 2°C (2 to 4°F).

A-9 (Day)--Moderately heavy concentrations of brown algae were observed in this dock area as sketched in Figure V-5. The heavy brown color of the water precluded the detection of Proctor and Gamble Company Outfall 001 reported to be discharging about 2,400 m^3/day (0.6 mgd) of cooling water.

A-9 (Night)--Water warmer than ambient harbor water was flowing out of this triangular shaped area into the Harbor as seen in the night thermal map [Figure V-3] and the isarthermal sketch [Figure V-4]. The Proctor and Gamble Company Outfall 001 could have been the source of the warm water.

A-10 (Day)--A thermal discharge(s) was recorded at this location as shown in the day IRLS thermal map [Figure V-6]. Amstar Corporation reported a discharge of condenser water averaging 76,800 m^3/day (20.3 mgd) at this location. The temperature within the thermal field near the discharge was estimated to be about 1 to 2°C (2 to 4°F) warmer than the ambient temperature of the Harbor waters. The discharge had a pronounced effect upon the color of the receiving water as shown in Figure V-5. The Harbor waters were quite turbid, displaying a yellow-gray color, while the water within the thermal plume was dark gray-green. There was a noticeable damping of the surface capillary waves in the field.

A-10 (Night)--A comparison of the day and night thermal maps of this area [Figures V-3 and V-6] indicates that the thermal plume was much larger at night. As shown in the isarthermal sketch of the night

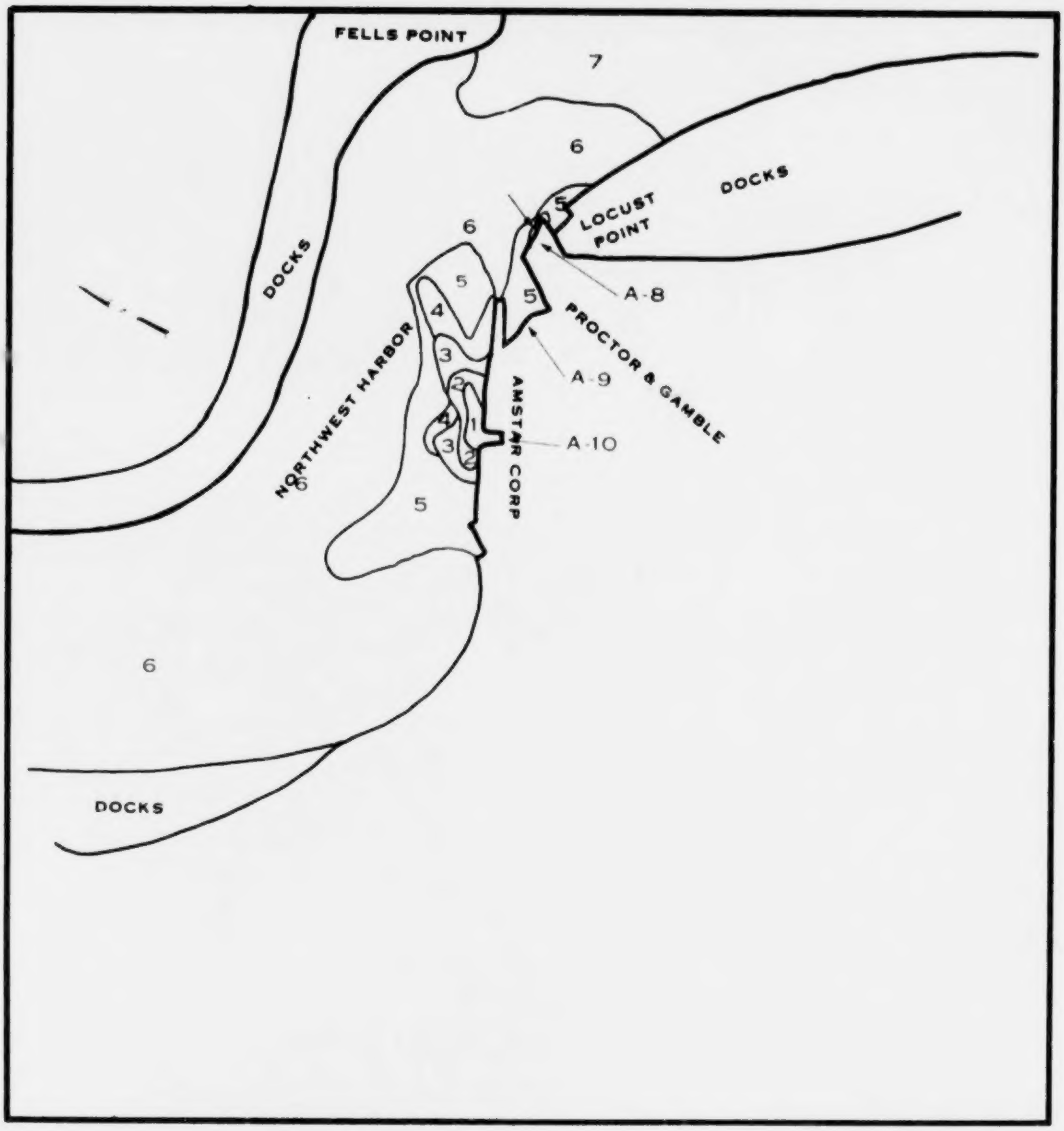

FELLS POINT
7
6
DOCKS
LOCUST POINT
5
6
DOCKS
5
4
5
A-8
PROCTOR & GAMBLE
3
2
A-9
NORTHWEST HARBOR
1
4
3
2
A-10
AMSTAR CORP
5
6
6
DOCKS

Figure V-4 Isarthermal Map (Night) - Central Northwest Harbor

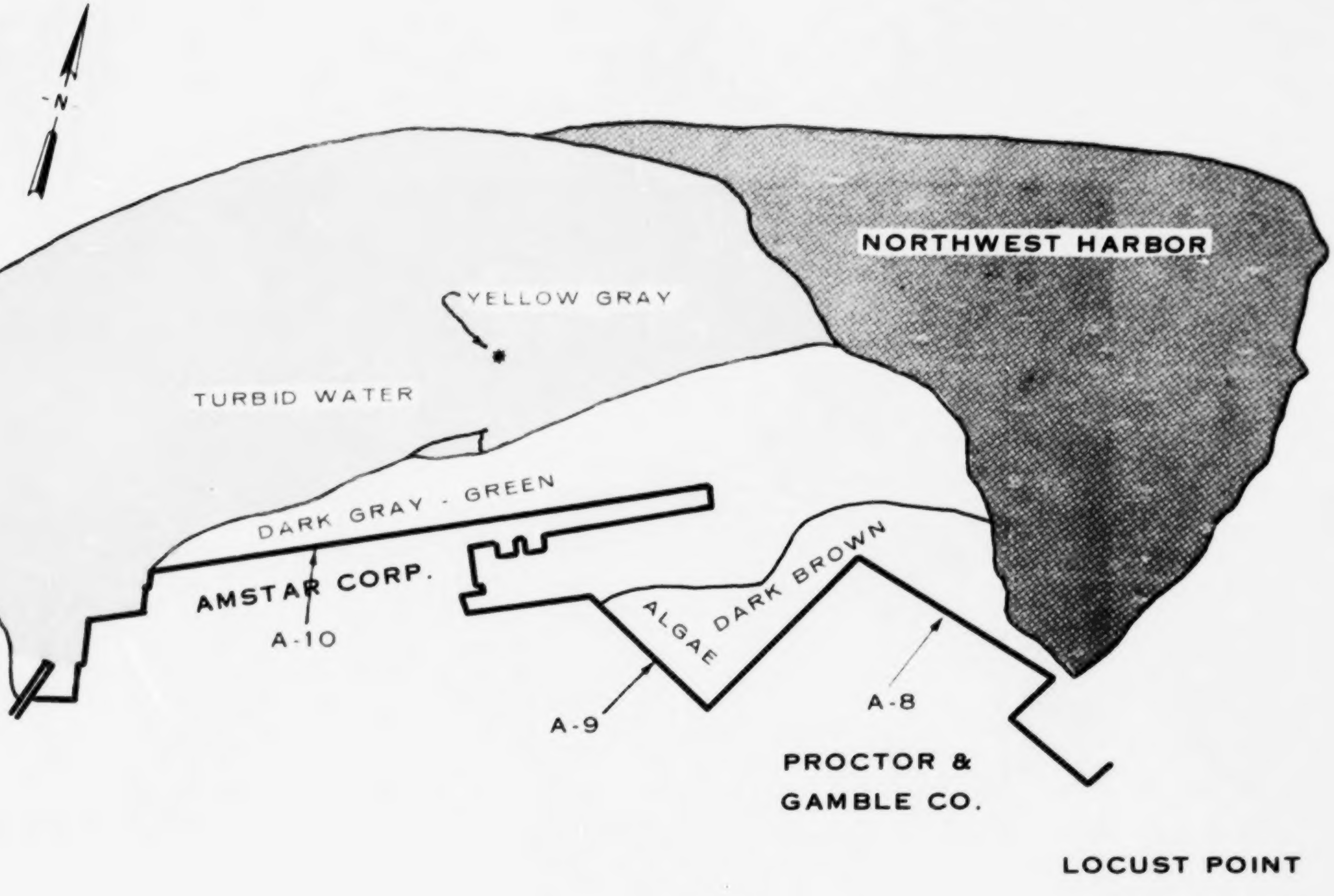

N
NORTHWEST HARBOR
YELLOW GRAY
TURBID WATER
DARK GRAY - GREEN
AMSTAR CORP.
A-10
ALGAE
DARK BROWN
A-9
A-8
PROCTOR &
GAMBLE CO.
LOCUST POINT

Figure V-5 Detailed Observations - Central Northwest Harbor

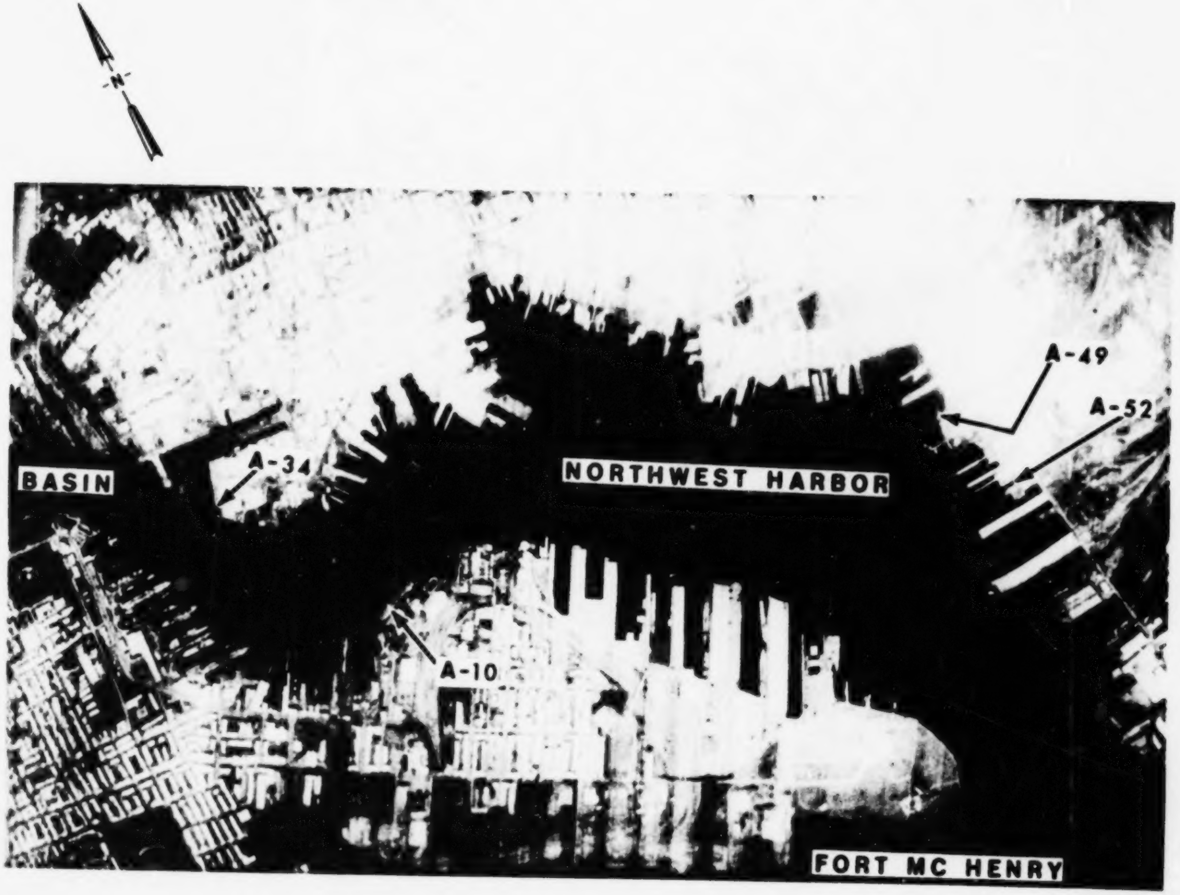

N
BASIN
A-34
NORTHWEST HARBOR
A-49
A-52
A-10
FORT MC HENRY

Figure V-6 Thermal Map (Day) - Northwest Harbor

discharge [Figure V-4], the warmest area of the plume (No. 1) extends into the dock/building area. The source of the condenser water is physically located at this position within the Amstar Corporation building. The temperature difference between a point in the plume near the discharge and the background Harbor waters was estimated to be 5 to 7°C (9 to 13°F). The tide was in a minor flood phase during the mission.

A-11 (Night)*--The water in this particular area was about 0.5 to 1.0°C (1 to 2°F) warmer than the ambient Harbor waters. No distinct discharge was detected. One known minor discharge is located at the dock position indicated by the leftmost arrow in Figure V-2; however, this outfall reportedly has a flow rate of only 1.5 m^3/day (400 gpd), hardly enough to heat this large area in the Harbor.

A-12 (Night)--The surface waters of this dock area were warmer by 0.5 to 1.0°C (1 to 2°F) than the background Harbor waters. This indication could not be directly related to a particular discharger. The only known waste source in this location is Outfall 010 of the Bethlehem Steel Corporation which reportedly discharges about 5.3 m^3/day (1,400 gpd) of acetylene generator drain water having an approximate discharge temperature of 32°C (90°F) during the summer months.

A-13 (Night)--About one half of the water in this dock area was 0.5 to 1.0°C (1 to 2°F) warmer than the ambient Harbor water, which could not be directly attributed to a particular discharge. Bethlehem Steel Corporation reported a condensate drain in this area with a flow rate of 0.4 m^3/day (100 gpd) at a summer temperature up to 60°C (140°F).

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* Observations A-11 through A-14 were not covered photographically during the day mission but were covered with the IRLS.

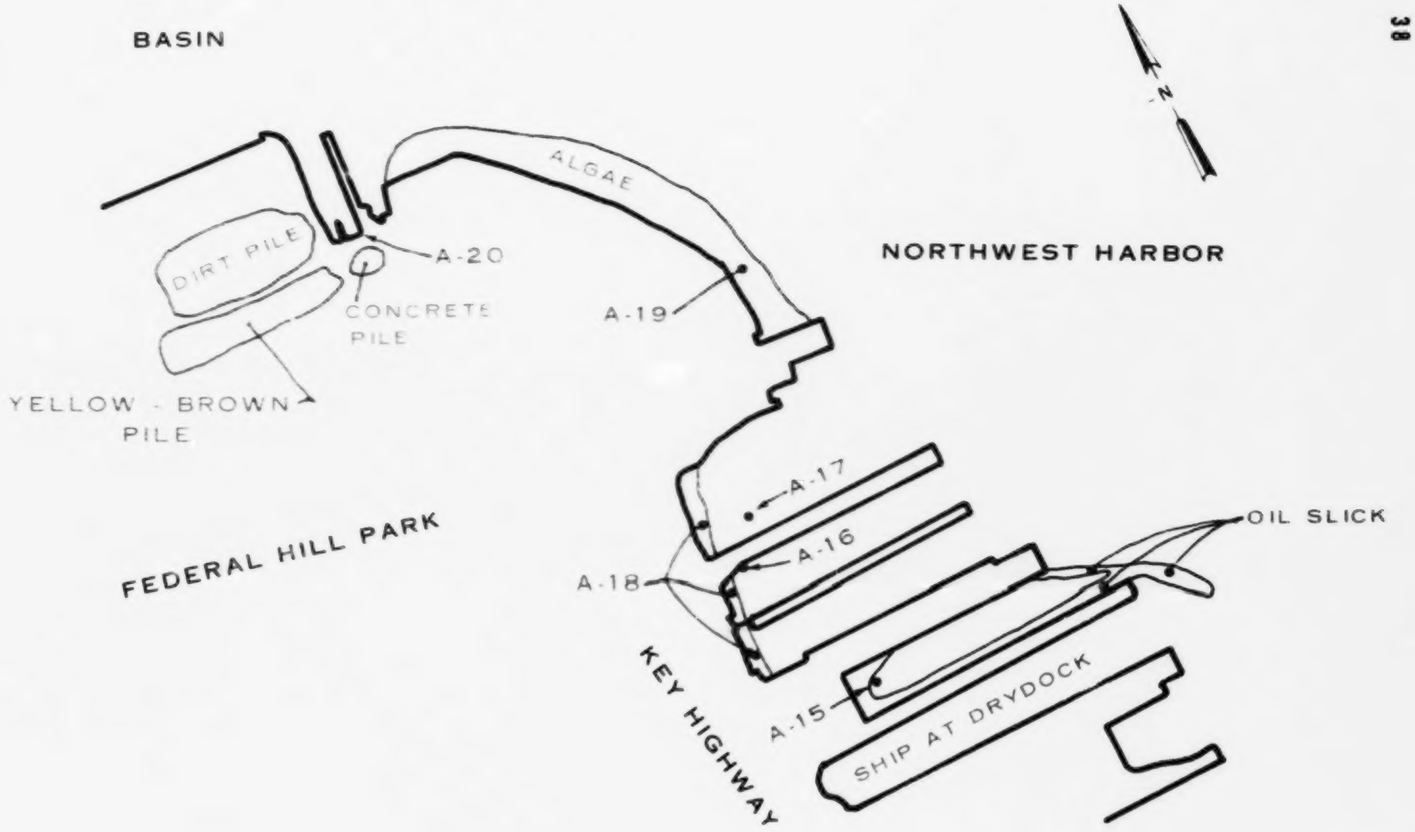
BASIN
NORTHWEST HARBOR
N
ALGAE
DIRT PILE
A-20
CONCRETE PILE
A-19
YELLOW - BROWN PILE
A-17
FEDERAL HILL PARK
A-16
A-18
OIL SLICK
KEY HIGHWAY
A-15
SHIP AT DRYDOCK

Figure V-7 Detailed Observations - Upper Northwest Harbor

A-14 (Night)--A small area of the surface waters in this dock area was warmer than the ambient Harbor water by about 0.5°C (1°F). No discharge was recorded in the airborne data. Bethlehem Steel Corporation reported a condensate drain (008) in this immediate area with a flow rate of 0.23 m^3/day (60 gpd) at a temperature of about 60°C (140°F) during the summer months.

A-15 (Day)--An oil slick was present in this dock area at the time of flight. It contained about 20 liters (5 gal.) of oil. The point indicated by the arrow in Figure V-7 had the characteristics of a submerged discharge which displayed a light gray color at the water surface and the presence of oil. This area is within the Bethlehem Steel Corporation complex but their RAPP permit application did not report a discharge at this location.

A-16 (Day)--A small, near-surface discharge having a light yellow-gray color, was recorded at this position [Figure V-7]. Bethlehem Steel Corporation reported two outfalls in this area of the dock facility discharging 1,500 m^3/day (0.405 mgd) of compressor drain water and 3 m^3/day (800 gpd) of boiler blowdown. These discharges are reported to have a summer temperature range of 36 to 40°C (97 to 104°F). No thermal discharge or thermal plumes were recorded at the time of flight. The discharge did not appreciably discolor the receiving water.

A-17 (Day)--A small area, resembling a low volume submerged discharge was recorded at this position. This area of influence was light gray in color yielding only slight discoloration in the receiving water.

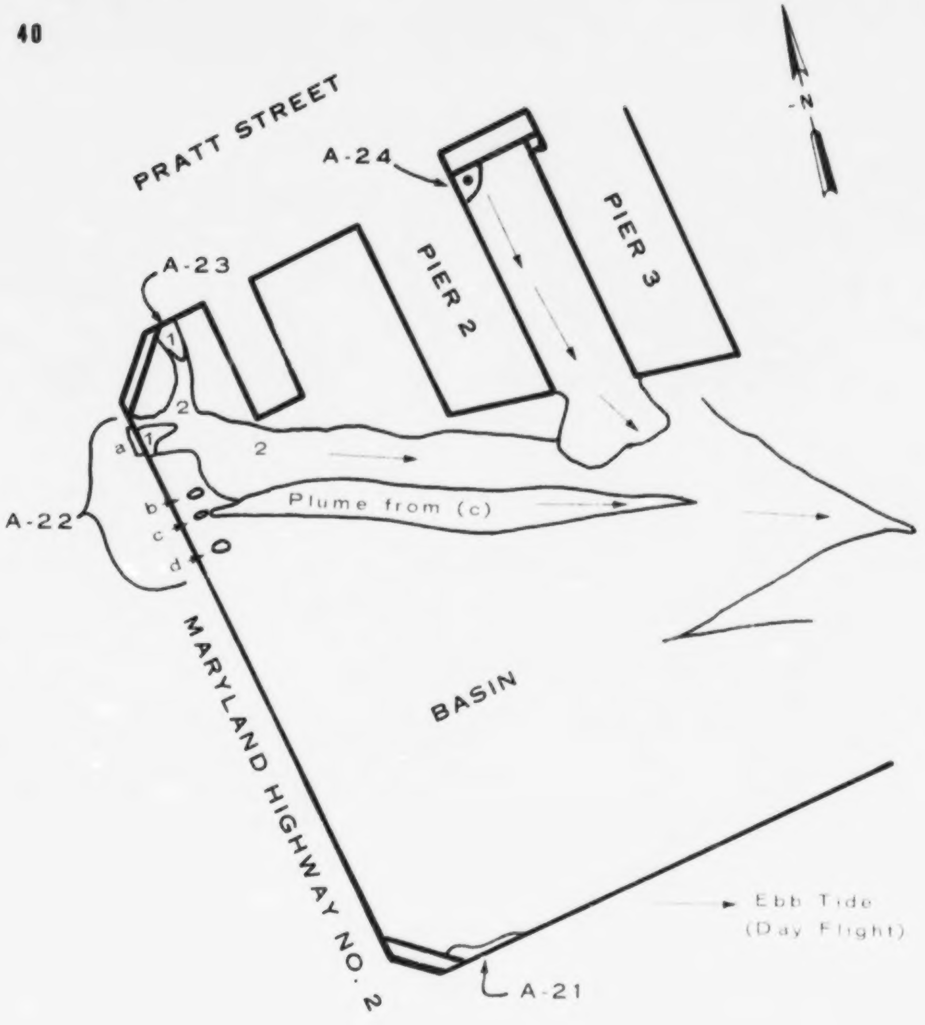
PRATT STREET
N
A-24
PIER 2
PIER 3
A-23
1
2
a
1
2
A-22
b
c
d
Plume from (c)
MARYLAND HIGHWAY NO. 2
BASIN
Ebb Tide
(Day Flight)
A-21

Figure V-8 Detailed Observations - Basin Area, Northwest Harbor

This indication was also within the Bethlehem Steel Corporation complex. Their permit application did not report the presence of a discharge at this point.

A-18 (Day)--These areas of the water surface were covered by three oil slicks containing less than 10 liters (3 gal.) of oil. The source of the oil could not be established.

A-19 (Day)--This area of the Harbor contained significant amounts of brown algae as indicated in Figure V-7.

A-20 (Day)--The yellow-brown substance in the pile shown in Figure V-7 was leaching into the water in this dock area. There was a pile of pieces of concrete positioned between the yellow-brown pile and the water resembling a landfill operation.

A-21 (Day)--The water within the Basin, as shown in Figure V-8, was a rather dark red-brown color exhibiting an appearance of high suspended solids. There is no record of a discharge in this particular location.

A-22 (Day)--Yellow-brown discharges were entering the Basin from numerous points in this area [Figure V-8]. At point "a", approximately 14 discrete plumes were observed in a distance of about 17 m (56 ft) along the embankment. Numbers 1 and 2 in Figure V-8 indicate levels or magnitudes of discoloration in the water with No. 1 being the greatest. Points "b" and "d" displayed characteristics of a boil from a submerged discharge. They did not further contribute significantly to discoloration of the Basin waters which were already quite turbid. Point "c" also had characteristics of a submerged discharge which contributed significantly to the yellow-brown discoloration of the Basin waters. It had a discrete plume as shown in Figure V-8. The relative magnitude of the resultant discoloration in the water was nearly No. 1.

A-22 (Night)--The effluent from point "a" was 1 to 2°C (2 to 4°F) warmer than the ambient Basin waters. The thermal field is shown in Figure V-3.

A-23 (Day)--A yellow-brown discharge, nearly identical in color to A-22 "a," was entering the Basin from the embankment position shown in Figure V-8. There were no temperature differences recorded.

A-24 (Day)--A brown-green discharge was entering the dock waters from this position. The resulting discoloration in this area was dispersing into the Harbor waters as shown in Figure V-8. A barge and crane were present at the time of flight, with other indications that suggested the construction of a superstructure in this area. There was also a small pond adjacent to the dock that contained water of identical color to that being discharged.

A-25 (Day)--The color of the water between Piers 3 and 6 was dark brown. This discolored water was slowly moving out into the Harbor area as shown in Figure V-2. The area between Piers 5 and 6 had the greatest discoloration. The dark brown color was not due to the presence of brown algae. The tide was in the ebb phase and the winds were from the northwest at 23 km/hr (14 mph) at the time of flight which explains the extent of the dispersal pattern shown.

A-25 (Night)--The water between Piers 4 and 5 as well as between Piers 5 and 6 was 1 to 2°C (2 to 4°F) warmer than the background Harbor waters. The warm water between Piers 4 and 5 was slowly dispersing into the Harbor while that between Piers 5 and 6 was not showing indications of dispersal. The tide was in a flood condition causing the warm water in the latter location to remain confined to the dock area.

A-26 (Day)--The outflow from this waterway (Jones Falls) was yellow-gray at the time of flight. The greatest discoloration was in the area labeled No. 1 while No. 2 was of a lesser magnitude [Figure V-2]. This water, indicative of high suspended solids, was slowly flowing out into the Harbor, also as shown. No discharges were visible in this waterway from Pratt Street to the Harbor.

A-26 (Night)--The water from this area was about 2°C (4°F) warmer than the ambient Harbor water near the Pratt Street crossover. The surface waters gradually cooled with only a minor thermal field extending out into the Harbor waters, as shown in Figure V-3. The tide was in flood condition at the time of flight, causing the warmer water to be retained in the upper reaches of this waterway.

A-27 (Day)--The water in the area indicated in Figure V-9 was yellow-gray in color. Some of the discoloration was the result of inflow of turbid water from Jones Falls (A-26). The cross-hatched areas in Figure V-9 were oil slicks. The amount of oil contained in the slicks was calculated to be 94 liters (25 gal.).

A-27 (Night)--The water in this area was about 1 to 2°C (2 to 4°F) warmer than the background Harbor waters [Figure V-3]. The warmer water was slowly moving out into the Harbor.

A-28 (Day)--There was a concrete opening in the embankment at this position at the end of Central Avenue [Figure V-9]. It appeared to be

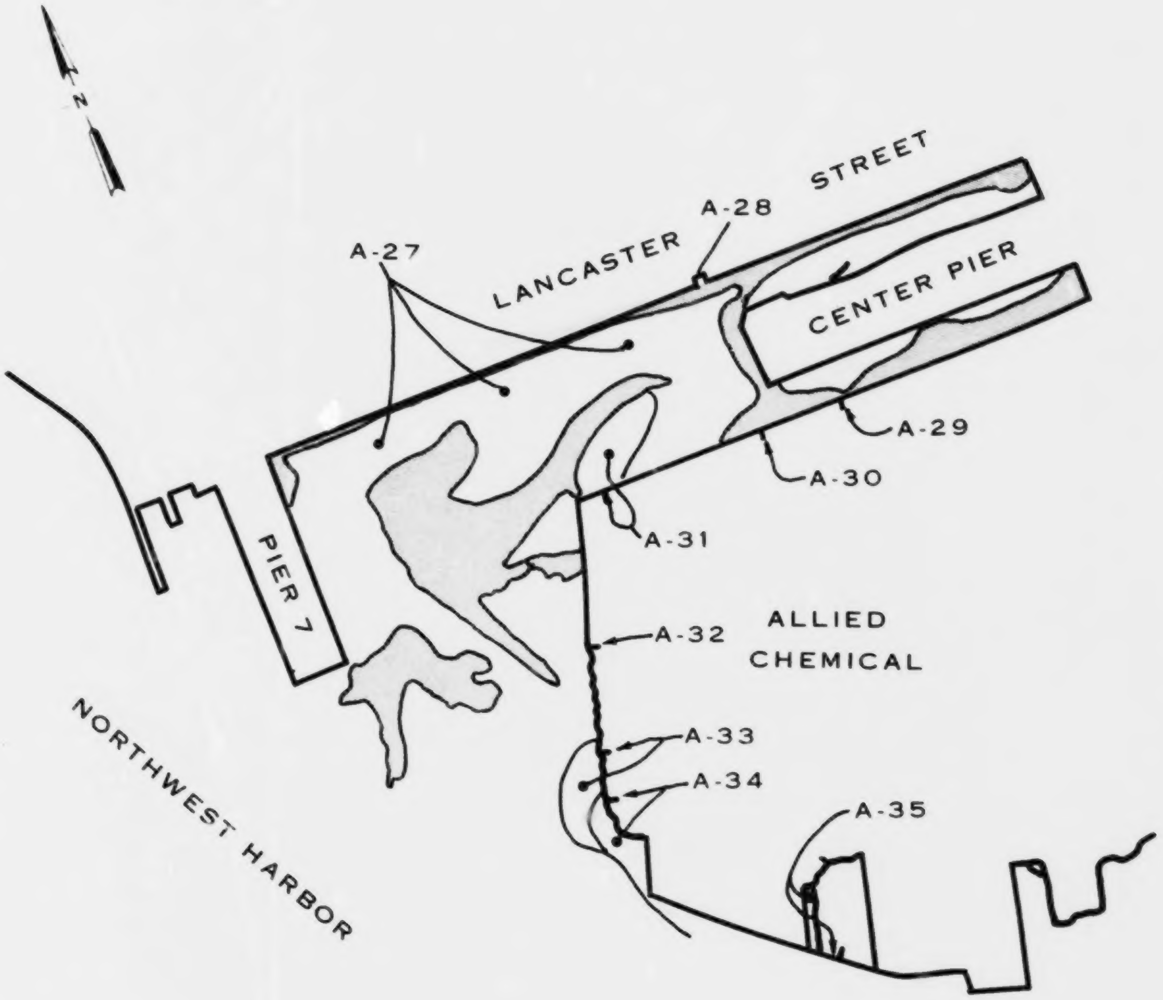
N
LANCASTER STREET
CENTER PIER
A-27
A-28
A-29
A-30
A-31
PIER 7
ALLIED CHEMICAL
A-32
A-33
A-34
A-35
NORTHWEST HARBOR

Figure V-9 Detailed Observations - Center Pier Area, Northwest Harbor

an outlet for a storm drain system which may have possibly contributed to the turbid condition of the water in this area.

A-29 (Day)--Outfall No. 001 from the Allied Chemical Corporation facility was not visible at the time of flight because a barge was docked at this shore position. This discharge reportedly consists of cooling water with a discharge flow rate of 230 m^3/day (0.06 mgd) and a summertime discharge temperature of 23°C (74°F).

A-29 (Night)--The entire surface area of the receiving water was warmer than the background Harbor waters. No isolated thermal plume was distinguishable in the airborne data.

A-30 (Day)--Outfall No. 002 (Allied Chemical Corporation) was also not visible at the time of flight. This discharge reportedly consists of boiler blowdown with a flow rate of 26 m^3/day (7,000 gpd).

A-31 (Day)--Allied Chemical Corporation was discharging wastewater from this location at the time of flight. The effluent created no significant discoloration in the receiving water. The extent of the plume, as indicated by the damping of surface capillary waves, is shown in Figure V-9. This outfall (No. 003) reportedly has a flow rate of 1,200 m^3/day (0.315 mgd) and an approximate summertime discharge temperature of 27°C (80°F).

A-31 (Night)--This discharge should have significantly influenced the night surface water temperatures discussed in A-27.

A-32 (Day)--A small volume of water adjacent to shore at this position was less turbid than the balance of the receiving water, which is indicative of a discharge that is reasonably clear with no great amounts of

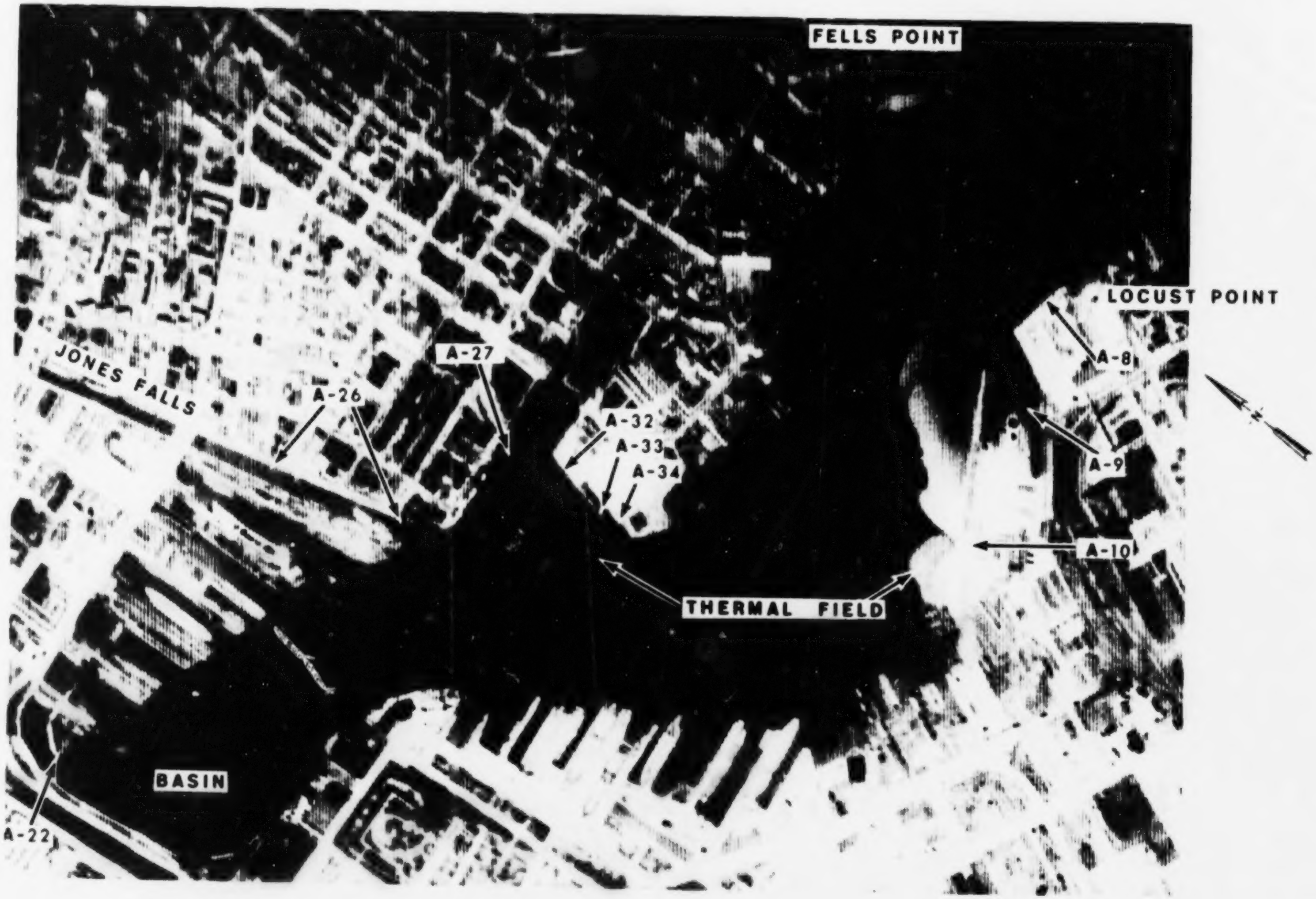
FELLS POINT
LOCUST POINT
JONES FALLS
A-27
A-26
A-32
A-33
A-34
A-8
A-9
A-10
THERMAL FIELD
BASIN
A-22
N

Figure V-3 Enlarged Thermal Map (Night) - Northwest Harbor

suspended solids or discoloration. Allied Chemical's Outfall 004 is located at this position with a reported flow rate of 1,780 m^3/day (0.47 mgd) and a summertime discharge temperature of 34°C (94°F).

A-32 (Night)--This discharge could have contributed significantly to the warm-water condition in this area. As shown in Figure V-3, the water along this embankment is slightly warmer (lighter gray) than that in the remainder of the waterway. No distinct thermal plume could be linked to this discharge.

A-33 (Day)--Allied Chemical Corporation's Outfall 005 was discharging a yellow-brown wastewater (process water) creating a small plume as shown in Figure V-9. The tide was in an ebb phase at the time of flight causing the plume to disperse into Harbor waters. The discharge flow rate and summertime temperature were reported as 1,500 m^3/day (0.39 mgd) and 34°C (93°F) respectively.

A-33 (Night)--This discharge in addition to Outfall 004 (A-32) could have contributed significantly to the warm water effect observed in this area of receiving water [Figure V-3]. The combined flow rate (004 and 005) would have been 3,300 m^3/day (0.86 mgd) at an approximate weighted temperature of 34°C (94°F).

A-34 (Day)--Allied Chemical Corporation's Outfall 006 was discharging a wastewater containing significantly less discoloration than that recorded in the receiving water. The shape of the resultant plume is shown in Figure V9. There was a very small thermal plume adjacent to this shore position as seen in Figure V-6. This outfall has a reported flow rate of 7,750 m^3/day (2.0 mgd) and a summertime discharge temperature of 32°C (90°F). This effluent reportedly contains process water.

A-34 (Night)--A thermal plume resulting from Outfall 006 was about 1.5 to 2.0°C (3 to 4°F) cooler than the ambient Harbor waters and 3.0 to 4°C (5 to 6°F) cooler than the overall surface temperature of the receiving waters. The cool (darker) thermal plume is shown in Figure V-3. Note that the field is moving out into the Harbor even though the tide is in the flood phase.

A-35 (Day)--There was a skimmer placed across the mouth of this slip [Figure V-9]. The water in the slip along the western boundary was heavily discolored yellow-brown. There was no evidence of an active outfall recorded.

A-36 (Day)--A yellow-gray substance was leaching into the Harbor waters discoloring about 1,500 m^2 of surface area. There was no evidence of an outfall in the airborne data.

A-37 (Day)--The water in this area of the Northwest Harbor was dark brown. The airborne data indicated the presence of brown algae due to a trace of chlorophyll recorded in the near-surface waters. There was a definite line of demarcation between the dark brown water and the greenish water in the outer Harbor. No wastewater discharges were found in this area.

A-38 (Day)--The water contained in the plume shown in Figure V-2, was very dark brown and contained brown algae. There were no detectable signs of an outfall at this position on the dock.

A-39 (Day)--The water in this area was nearly all dark brown, partially due to the presence of brown algae. Along the eastern side of this dock, as indicated by the red arrow on Figure V-2, there was a small, yellow-brown plume with characteristics indicative of a small submerged outfall, although no positive source was found.

A-40 (Day)--A yellow-gray substance was recorded in the near surface waters [Figure V-2]. The greatest concentration occurred in the northwest corner of this rectangular dock area which was suspected to contain the source. The balance of this dock area was dark brown in color and contained significant amounts of brown algae.

A-41 (Day)--This area of water contained large areas of dark brown water and brown algae.

A-42 (Day)--Numerous oil slicks containing about 60 liters (15 gal.) of refined oil were located in this particular water area. The source of the oil could not be readily determined from the airborne data.

A-43 (Day)--This pentagon shaped area [Figure V-2] of water was not photographically covered during the mission. It was imaged with the infrared line scanner with no thermal discharges recorded.

A-43 (Night)--There were no thermal discharges recorded in this area at night.

A-44 (Day)--There was a yellow-brown substance in the water of this area [Figure V-2]. The degree of discoloration was greatest where labeled No. 1, while those areas labeled No. 2 and 3 were less discolored. The source was probably within the area labeled No. 1. There was a semicircular storm drain opening in the area labeled No. 2, as indicated by the arrow.

A-45 (Day)--There were numerous oil slicks (containing refined oil)

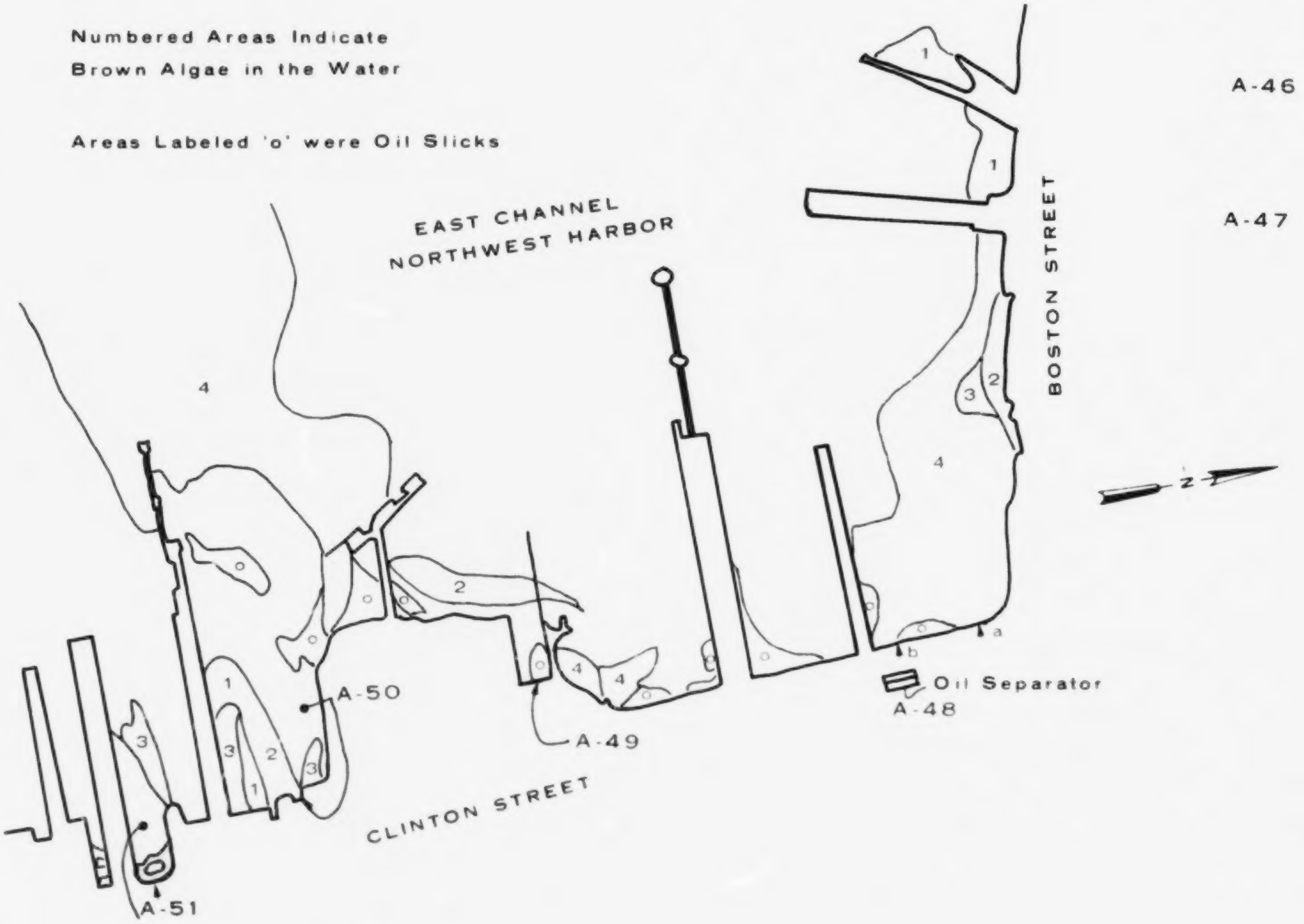
Numbered Areas Indicate
Brown Algae in the Water
Areas Labeled 'o' were Oil Slicks
EAST CHANNEL
NORTHWEST HARBOR
BOSTON STREET
CLINTON STREET
A-46
A-47
A-48
A-49
A-50
A-51
Oil Separator
N
a
b
1
2
3
4
o

Figure V-10 Detailed Observations - Eastside, Lower Northwest Harbor

in this particular area of the Harbor waters [Figure V-2]. The amount of oil contained in these slicks was calculated to be about 827 liters (219 gal.).

A-46 (Day)--The numbered areas in Figure V-10 indicate the relative concentration of dark brown water and the presence of brown algae in a blooming state with No. 1 representing the heaviest relative concentration of the brown effect and No. 4, the least concentration.

A-47 (Day)--The areas in Figure V-10 labeled with the letter "O" contained numerous oil slicks. The total amount of oil in the slicks was calculated to be about 54 liters (14 gal.).

A-48 (Day)--According to Exxon Oil and Refining Company's RAPP permit application, their Outfall 001 is located at Position "a" in Figure V-10. At the time of flight there was no active discharge at this position. Instead, there were characteristics of a submerged discharge at position "b". Either there were two outfalls in this area or Outfall 001 was located at position "b" rather than "a". Outfall 001 discharges effluent from the oil separator, located adjacent to shore [Figure V-10] with a reported flow rate of 61 m^3/day (16,000 gpd) and a summertime discharge temperature of 28°C (82°F). There were two oil slicks in this area along with one patch of grease on the water's surface. Outfall 001 was most probably the source of the oil and grease.

A-49 (Day)--Exxon's Outfall 002 was discharging a small amount of a yellow-brown wastewater into this area. A small heavy oil slick was adjacent to the outfall shore position. Oil slicks of any significance

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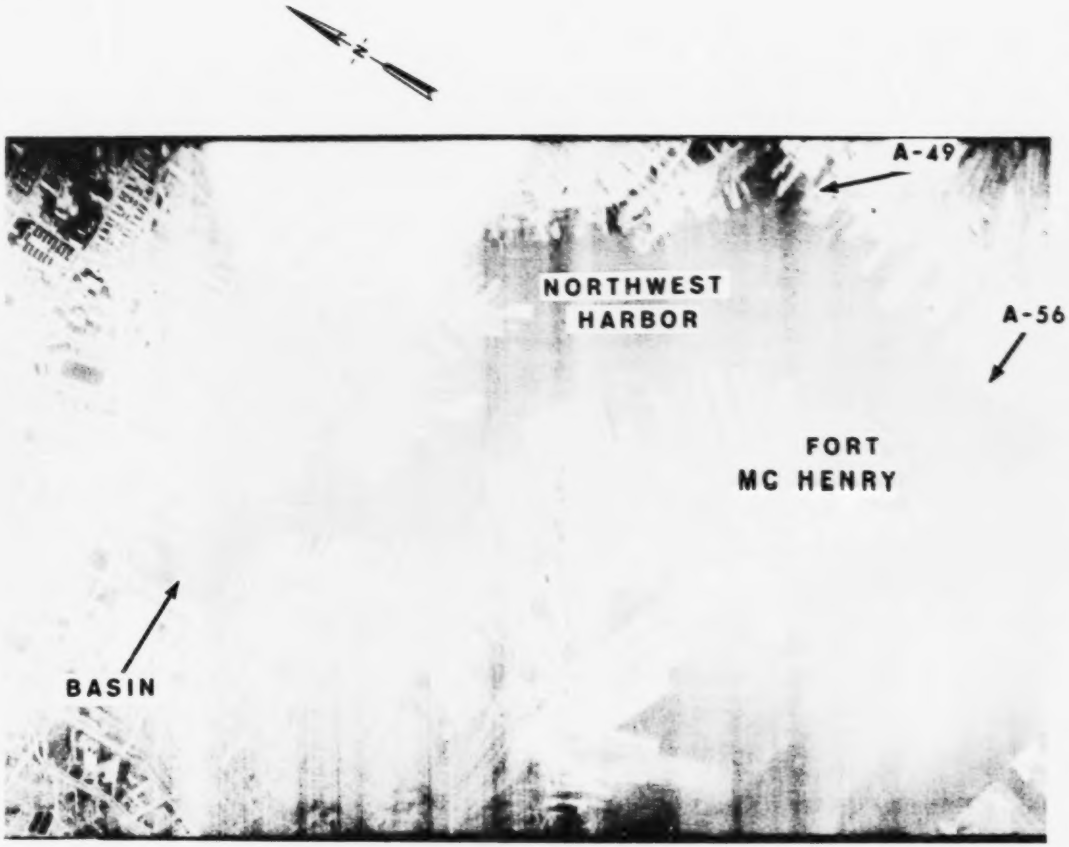

N
A-49
NORTHWEST
HARBOR
A-56
FORT
MC HENRY
BASIN

Figure V-11 Thermal Map (Night) - Northwest Harbor

were quite a distance from this outfall [Figure V-10] indicating that this discharge, an oil separator effluent, was most probably the source of the oil at the outfall. This discharge has a reported flow rate of 590 m^3/day (0.156 mgd) with a summertime discharge temperature of 32°C (90°F). A small thermal plume was recorded at the discharge [Figure V-6].

A-49 (Night)--The effluent from this outfall was several degrees (Centigrade) warmer than the ambient Harbor waters. The thermal field is shown in Figure V-11.

A-50 (Day)--The color of the water in this area was dark yellow-brown characterized by absence of the brown algae. A moderate discharge identical in color to the receiving water was detected in this area [Figure V-10]. There were also moderate amounts of small debris on the water surface in this area.

A-51 (Day)--An elevated outfall was discharging a yellow-green wastewater into the dock waters. A heavy yellow-green foam was floating on the water surface around the impact point [Figure V-10]. The heavy or dense areas of this foam had an inherent optical reflectance characteristic in the near infrared region. This is most usually the fingerprint of algae (chlorophyll) in water. The true color data clearly shows that this effect was definitly not brown algae. The true color character of the foam was similar to that of green algae which is atypical of an industrial wastewater. Because of the lack of ground truth, the constituents of this foam-like substance could not be ascertained. The diameter of the outfall pipe was only 24 cm (10 in.).

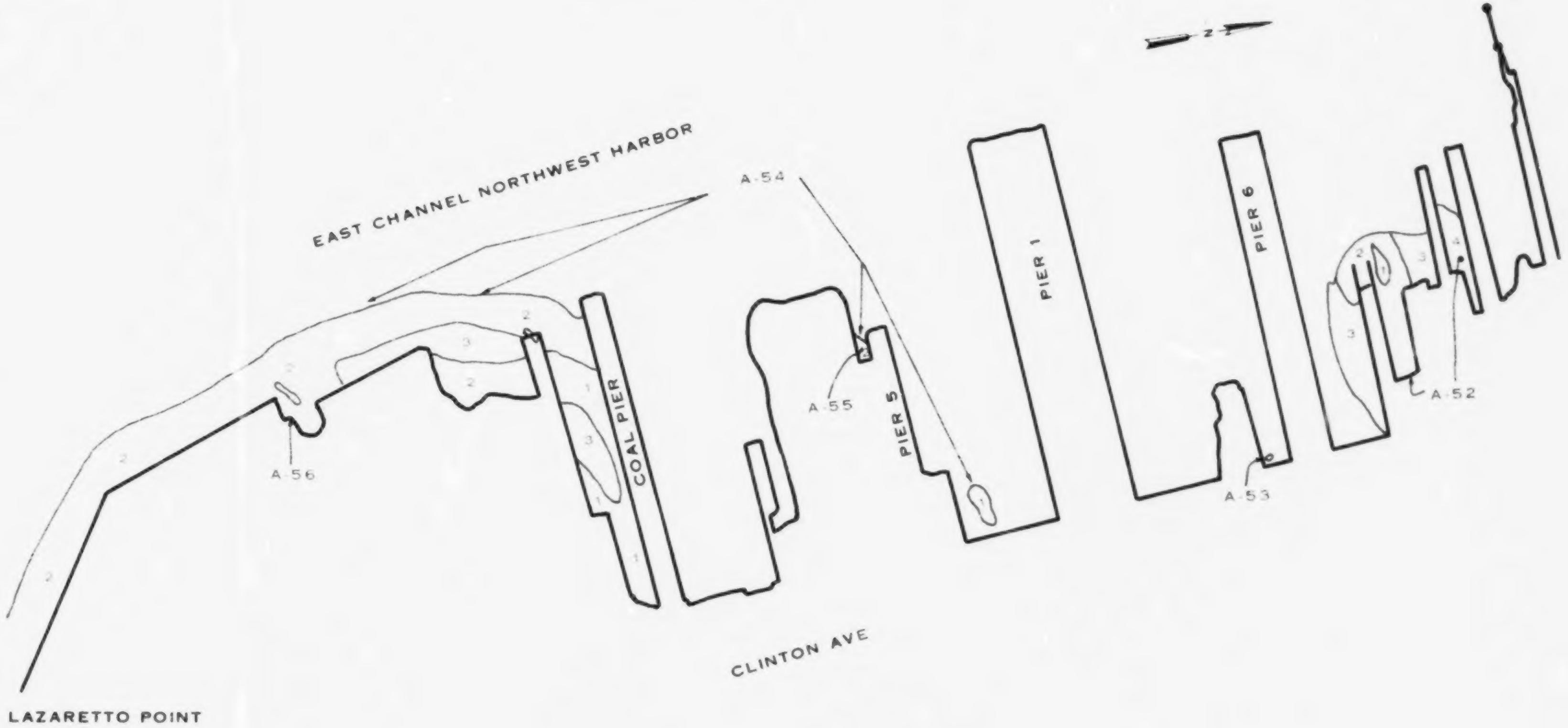

EAST CHANNEL NORTHWEST HARBOR
A-54
A-55
A-56
A-53
A-52
COAL PIER
PIER 5
PIER 1
PIER 6
N
CLINTON AVE
LAZARETTO POINT
1
2
3
4

Figure V-12 Detailed Observations - Lazaretto Point; Lower Northwest Harbor

A-52 (Day)--A yellow-gray wastewater was being discharged into this dock area. No outfall was visible. A brief isoconcentration analysis performed upon the airborne true color data revealed that the greatest discoloration appeared in the small area labeled No. 1 near the end of the dock [Figure V-12]. Nos. 2 and 3 represent areas of lesser discoloration. There was only a minor temperature difference between this plume and the Harbor waters [Figure V-6]. The area also marked by A-52 and No. 4 [Figure V-12] contained the same discoloration but of a lesser magnitude.

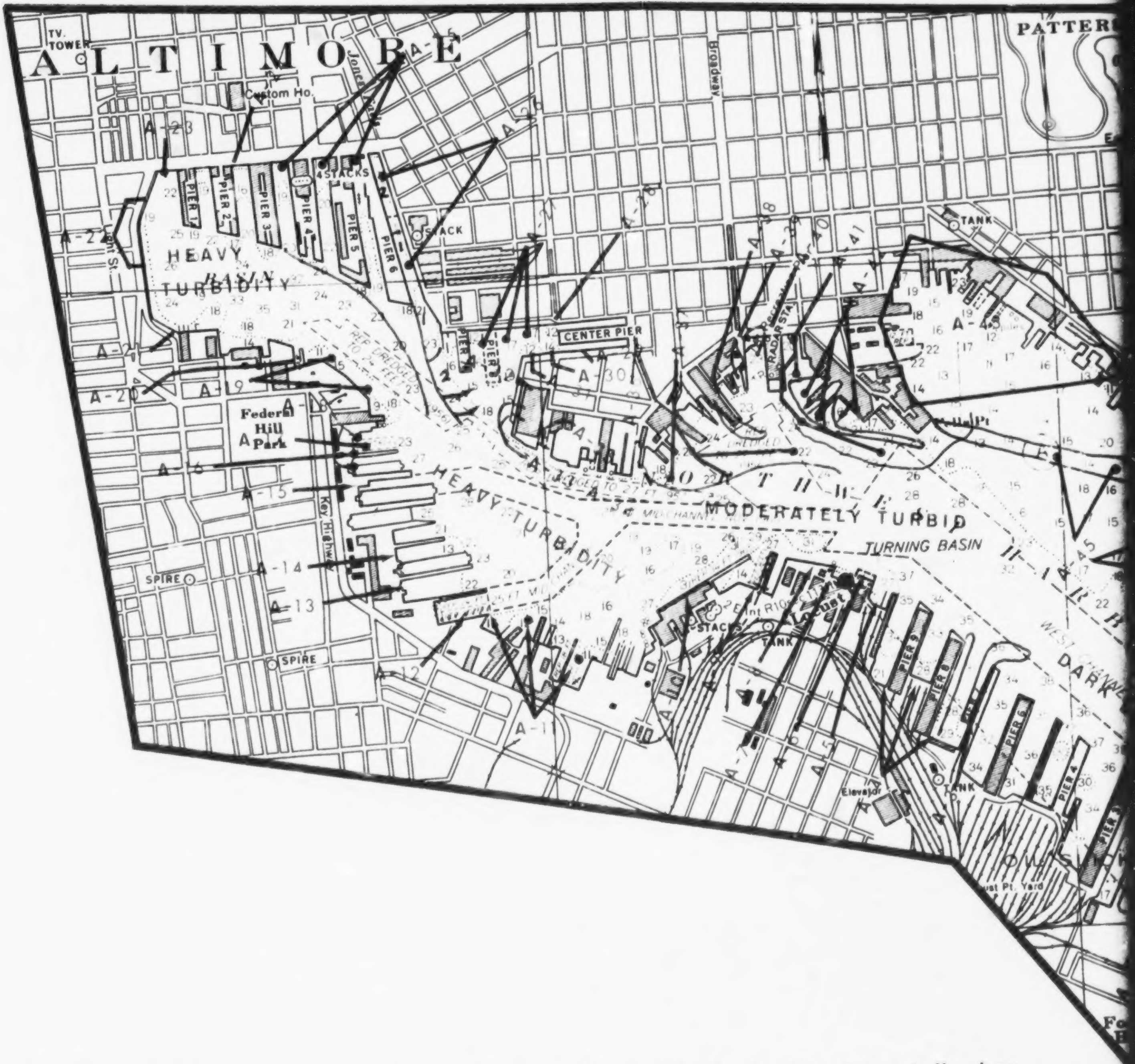
A-53 (Day)--A possible surface or near-surface outfall was located at this position, about 3.8 m (12 ft) from the corner or apex of the dock. The general water color in this area was very dark brown and the disturbance in the water at this suspected position was somewhat lighter brown with evidence of some turbulence.

A-54 (Day)--Large and small patches of brown algae were present with the numbers reflecting the relative levels or concentrations of chlorophyll.

A-55 (Day)--A possible outfall, located 9.1 m (30 ft) from the apex of the dock and being 3.8 m (12.5 ft) in length before entering the water, was recorded at this position [Figure V-12]. The pipe diameter was about 20 cm (8 in.). There was no significant relative discoloration in the water other than from the presence of brown algae.

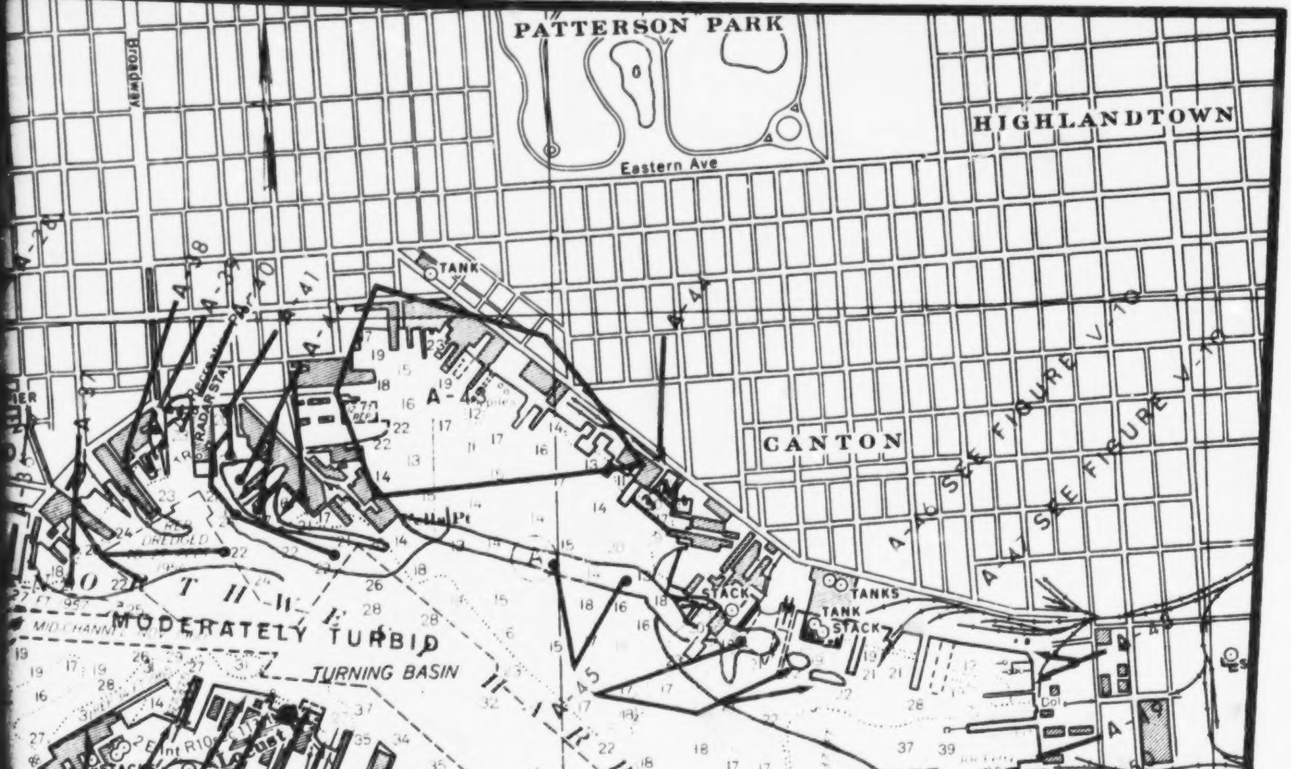
A-56 (Day)--A light-gray colored substance was entering the water at this point. A small area of surface foam was also present as shown in Figure V-12. A discrete outfall could not be seen from the airborne data.

A-56 (Night)--A warm effluent was entering the water at this shore position. The resultant thermal plume was about 2°C (4°F) warmer than the background Harbor waters. The plume or field was being carried northward with the flood tide as shown in Figure V-11.



ALTIMORE
TV. TOWER
Custom Ho.
Jones Falls
Broadway
PATTER
4 STACKS
STACK
PIER 1
PIER 2
PIER 3
PIER 4
PIER 5
PIER 6
CENTER PIER
HEAVY TURBIDITY
BASIN
Light St.
Federal Hill Park
Key Highway
HEAVY TURBIDITY
MODERATELY TURBID
TURNING BASIN
NORTHWEST HARBOR
WEST CHANNEL
DARK
SPIRE
SPIRE
STACKS
TANK
TANK
TANK
Elevator
PIER 9
PIER 8
PIER 6
PIER 4
Locust Pt. Yard
A-11
A-12
A-13
A-14
A-15
A-16
A-19
A-20
A-21
A-22
A-23
A-30
A-38
A-40
A-41
A-43

Figure V-2 Locations of Specific Observations - Area A, Northwest Harbor


PATTERSON PARK
Broadway
Eastern Ave
HIGHLANDTOWN
CANTON
TANK
TANKS
STACK
A-46 SEE FIGURE V-10
A-47 SEE FIGURE V-10
A-38
A-39
A-40
A-41
A-43
A-44
A-45
A-48
A-49
A-55
RADAR STA
DREDGED
MID-CHANNEL
NORTHWEST HARBOR
MODERATELY TURBID
TURNING BASIN
WEST CHANNEL
DARK BROWN
DARK BROWN
YELLOWISH GRAY
HEAVY TURBIDITY
EAST CHANNEL
STACKS
PIER 3
PIER 4
PIER 5
PIER 6
PIER 1
PIER 6
Pier 7
Elevator
Locust Pt. Yard
dolphins
piles
Fort Henry
TIDE DATA
Cable and Pipeline Area

- Area A, Northwest Harbor

MIDDLE BRANCH AND UPPER INNER HARBOR (AREA B)

This portion of the study area covers the Middle Branch and the segment of the Inner Harbor lying westward of a line extending southeastward from Fort McHenry to the Harbor Tunnel [see Figure V-13, a foldout located at the end of the Area B discussion, for more detail]. Middle Branch is the western terminus of the Inner Harbor. It extends about 3 km (2 mi) northwestward from the point where the Patapsco River enters the broad waters of the Harbor. Gwynns Falls, a small stream, enters the Branch from the west. Except in Spring Garden Channel, the northern portion of the Branch is shallow, with depths less than 1 m (3 ft) common. Channel depths are 6 to 8 m (20 to 25 ft). The western and eastern shorelines of the Branch are industrialized while the southern shore is relatively undeveloped.

The Patapsco River, the main source of freshwater inflow to Baltimore Harbor [see Section IV], enters the Inner Harbor from the southwest. Sediment deposition from the River has produced shallow water areas in most of the southwest quarter of this segment of the Inner Harbor. In contrast, the northern half of the Harbor is relatively deep, averaging more than 7 m (20 ft) with depths up to 12 m (40 ft) recorded. The northern shore is industrialized while the southern shore is relatively undeveloped.

Except during flood flows in Gwynns Falls, interchange of water in the Middle Branch is limited. The Patapsco River inflows coupled with the larger tidal prism increase the circulation within the Inner Harbor relative to Middle Branch but water movements are still limited.

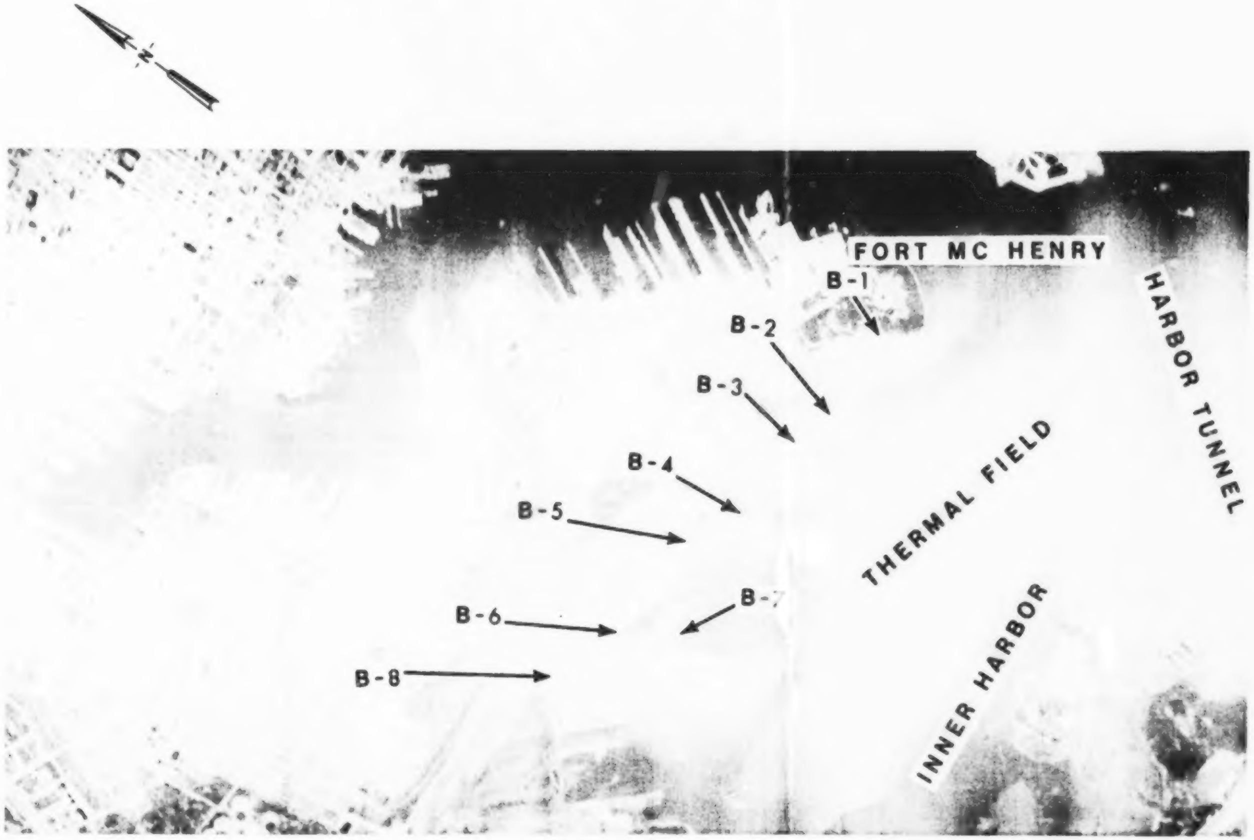

N
FORT MC HENRY
HARBOR TUNNEL
THERMAL FIELD
INNER HARBOR
B-1
B-2
B-3
B-4
B-5
B-6
B-7
B-8

Figure V-14 Thermal Map (Night) - Upper Inner Harbor

General Observations

The general color and thermal characteristics of the surface waters of Middle Branch and the upper portion of Inner Harbor are shown in Figure V-13. Middle Branch and the northern half of Inner Harbor were gray-brown in color and warm. In contrast, the mouth of the Patapsco River and southern half of Inner Harbor were heavily discolored a yellow-brown from suspended sediment, probably the result of the recent light rains. The thermal infrared imagery indicated that the Patapsco River inflow was significantly cooler than ambient Harbor waters. The line of demarcation between these two waters was pronounced, indicating that for the conditions observed, the Patapsco River inflow exerted little effect on water movements in Middle Branch and the north half of Inner Harbor.

Specific Observations

Identifying numbers for specific observations in Area B are overprinted in red on Figure V-13, a section of U.S. Coast and Geodetic Survey Nautical Chart 545.

B-1 (Night)*--A large thermal field was recorded in this area adjacent to the south edge of Fort McHenry National Monument. The thermal field is clearly visible as the light area in Figure V-14, an IRLS thermal map recorded by the night flight. The relative temperature levels are sketched in Figure V-15, an isarthermal map. The warmest

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* Observations B-1 through B-8 were not photographed or covered with the IRLS during the day flight.

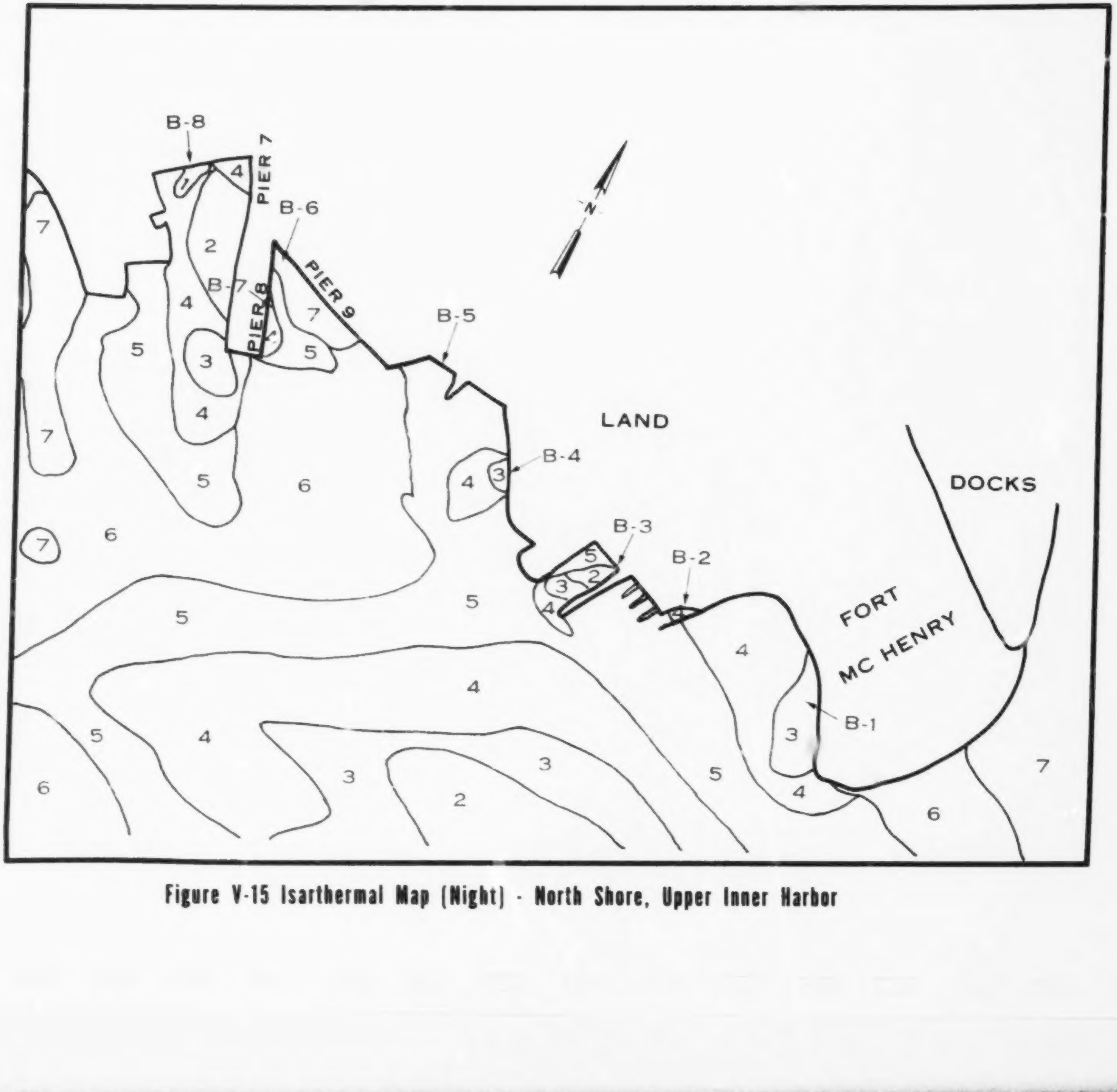
B-8
PIER 7
B-6
PIER 9
B-7
PIER 8
B-5
LAND
B-4
B-3
B-2
FORT
MC HENRY
DOCKS
B-1
N
7
4
2
4
5
3
7
5
4
7
5
6
6
7
4
3
5
2
3
2
4
5
5
5
4
4
3
3
2
5
4
3
6
6
7

Figure V-15 Isarthermal Map (Night) - North Shore, Upper Inner Harbor

surface water temperature is labeled No. 3. Thermal discharge was not detected but was probably in this particular location. The difference in surface temperature between the field and the dark gray background river water was estimated to be 2.5 to 3.0°C (4 to 5°F).

B-2 (Night)--A small thermal plume was recorded in this particular area [Figures V-14 and V-15]. The warm water could have been either from a small discharge or washed into this area from another source. The difference in temperature between this small thermal plume and the cooler river water was about 0.5 to 1.0°C (1 to 2°F).

B-3 (Night)--A moderate thermal plume was recorded at this point with the thermal discharge located in the eastern corner of the dock area [Figure V-14]. The relative temperatures within the thermal field are sketched on the isarthermal map, Figure V-15. The relative temperature difference between Area 2 and Area 5 was estimated to be 3 to 4°C (5 to 7°F).

B-4 (Night)--A large thermal field was recorded in this area as shown in Figure V-14. A positive source identification was not made, but the area adjacent to shore (labeled No. 3) had the warmest surface temperatures. The relative temperature difference between Nos. 3 and 5 was estimated to be 2 to 3°C (4 to 5°F).

B-5 (Night)--A small thermal plume with a temperature increase of only 0.5 to 1.0°C (1 to 2°F) was recorded at this location [Figure V-14]. The field was not sketched in Figure V-15 because the temperature difference was too small to be evaluated by the Image Analyzer for this specific laboratory test set-up. The source of the warm water may possibly have been at the shore position indicated by the arrow on Figure V-14.

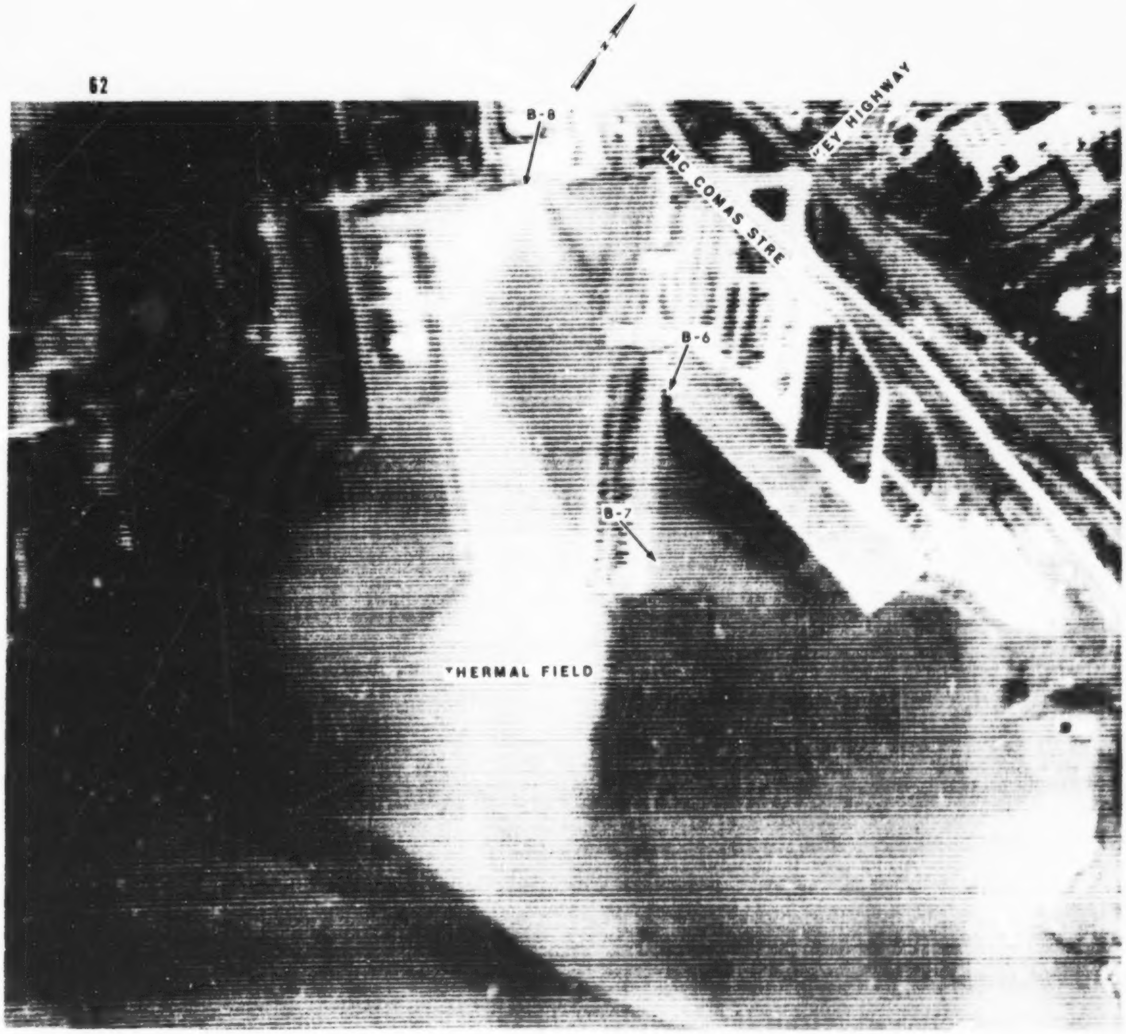
B-8
MC COMAS STRE
EY HIGHWAY
B-6
B-7
THERMAL FIELD

Figure V-16 Enlarged Thermal Map (Night) Upper Inner Harbor

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B-6 (Night)--A cool-water thermal field was emerging from the apex of this triangular shaped dock area as indicated on Figure V-14. All indications show that the source was at the apex. The infrared image of this area was enlarged about five times to better define the source of the cool water [Figure V-16]. The source is indicated by the arrow. The temperature difference between this cool field labeled No. 7 and the background river water labeled No. 6 was estimated to be 1 to 2°C (2 to 4°F) [Figure V-15].

B-7 (Night)--This warm thermal field (No. 4), generally 1 to 2°C (2 to 4°F) warmer than the background river water (No. 6), was recorded along the western side of the triangular dock area. It could not be determined if this field resulted from a discrete source in this area or if it was surface flow under the dock superstructure from indication B-8, discussed next.

B-8 (Night)--A large thermal effluent was recorded at this location, as shown in Figure V-14 and the enlarged thermal map in Figure V-16. The temperature difference between the discharge (No. 1) and the receiving water (No. 6) was estimated to be 5 to 7°C (9 to 13°F). The resultant thermal field extended halfway across the Inner Harbor. A detailed isarthermal sketch of this effluent and thermal field is presented in Figure V-17.

B-9 (Day)--A dark gray wastewater was present in these two areas [Figure V-13]. The one to the east of the rail car dock had a poorly maintained stormdrain or outfall structure inland and adjacent to the dark water. No flow into the Harbor waters was present at the time of flight.

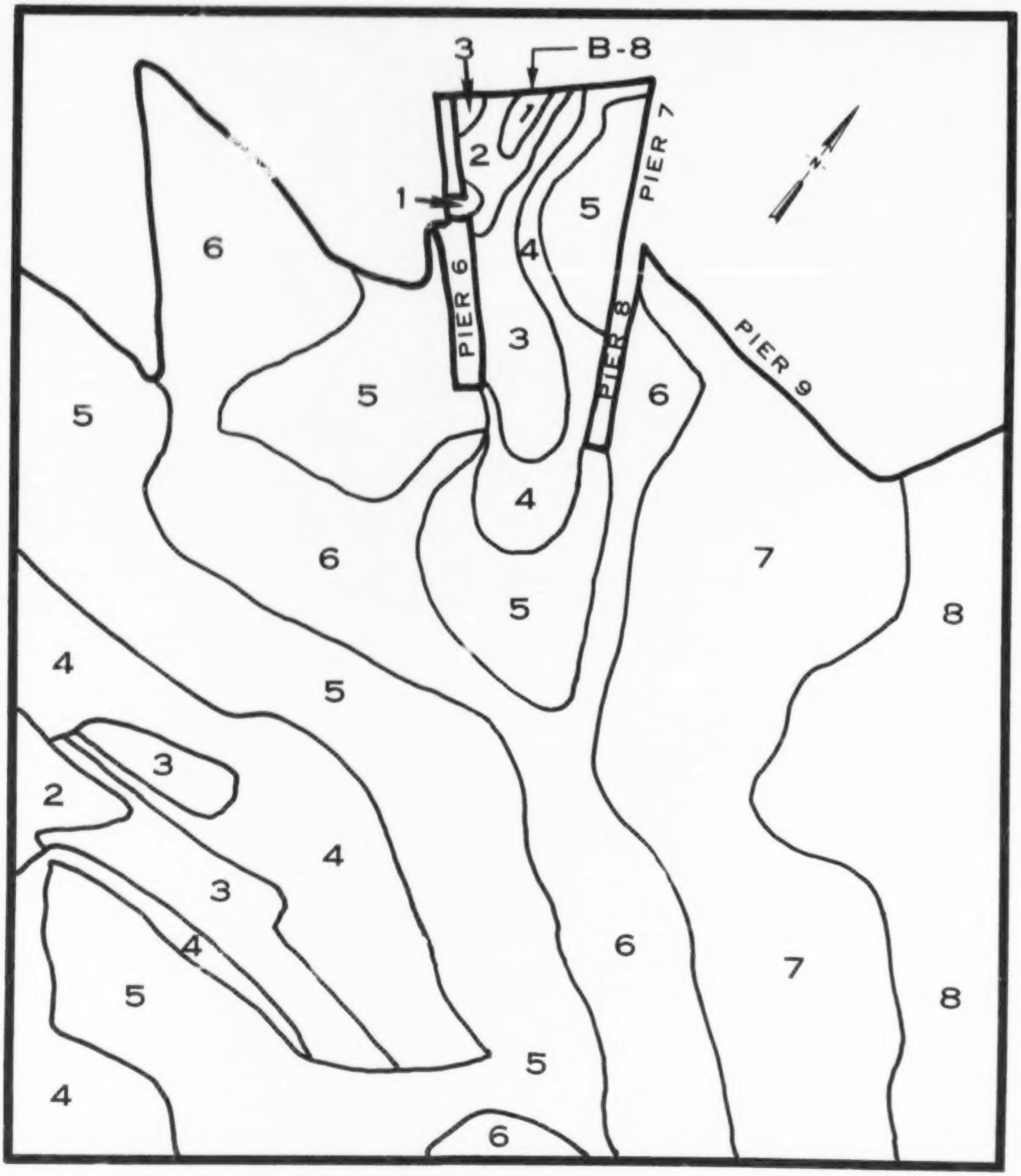
3
B-8
1
2
1
PIER 7
5
PIER 6
4
6
3
PIER 8
PIER 9
5
5
6
4
6
7
5
8
4
5
3
2
4
3
4
5
6
7
8
5
4
6
N

Figure V-17 Isarthermal Map of Outfall B-8 – Inner Harbor

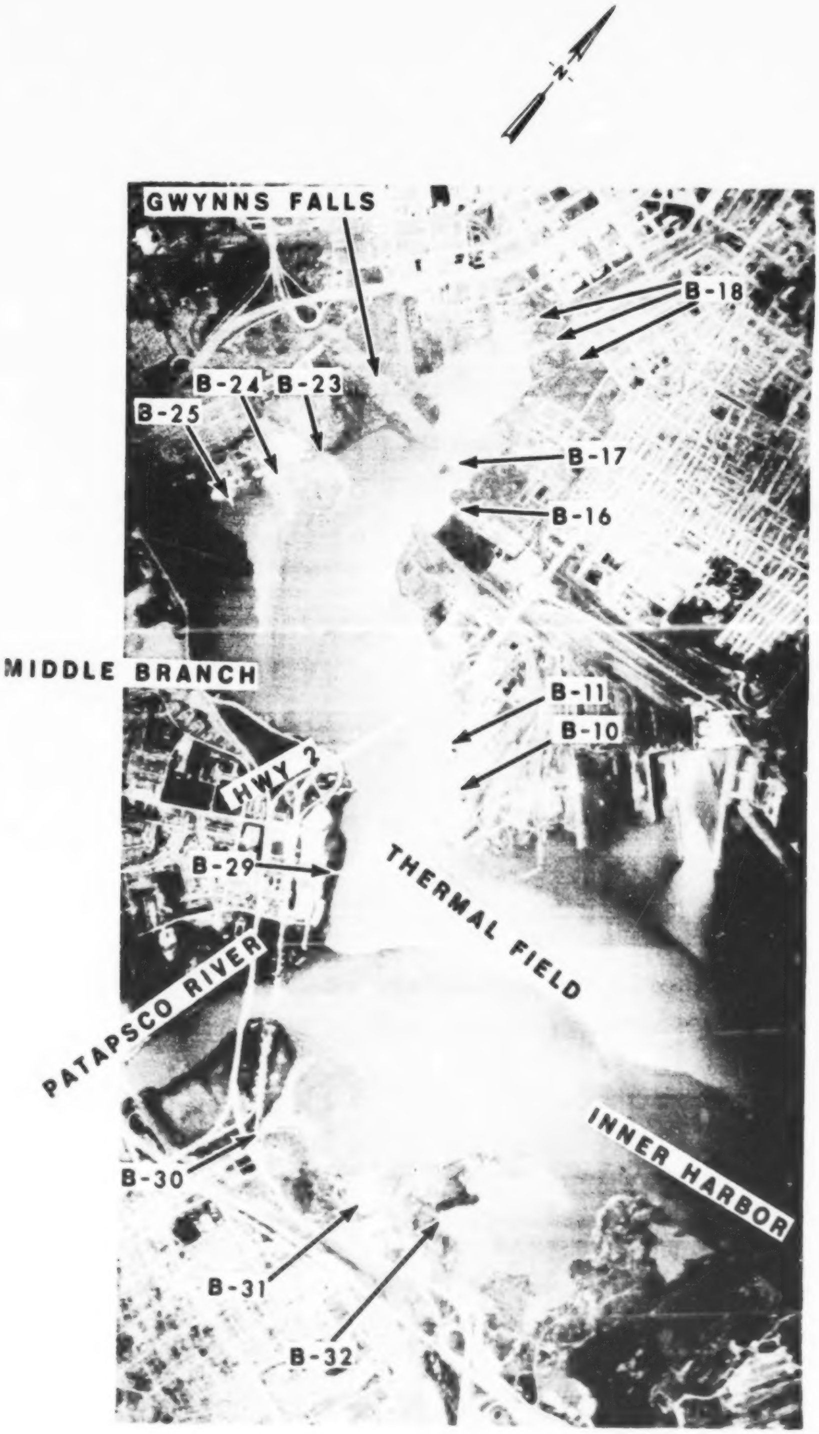
N
GWYNNS FALLS
B-18
B-24
B-23
B-25
B-17
B-16
MIDDLE BRANCH
B-11
B-10
HWY 2
B-29
THERMAL FIELD
PATAPSCO RIVER
INNER HARBOR
B-30
B-31
B-32

Figure V-18 Thermal Map (Night) - Middle Branch and Upper Inner Harbor

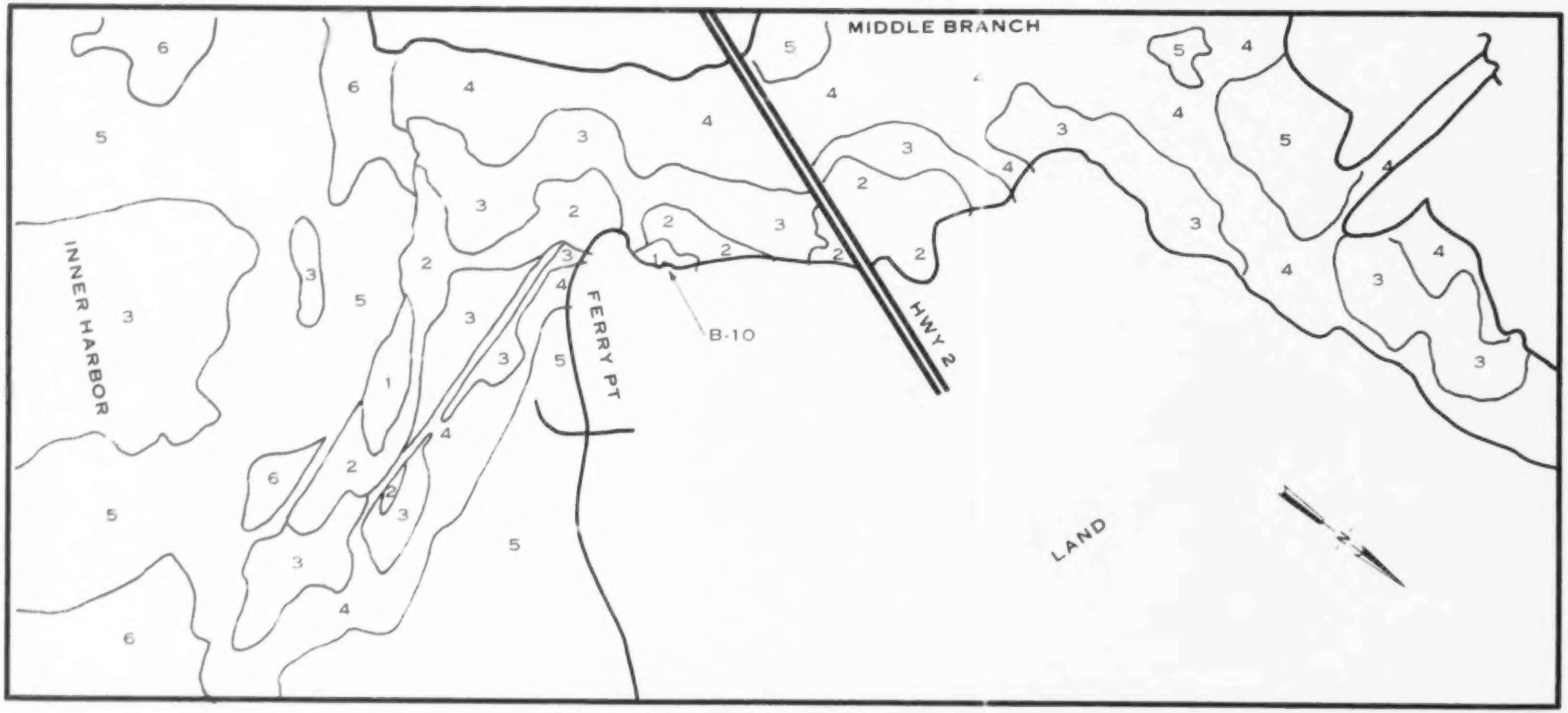
MIDDLE BRANCH
INNER HARBOR
FERRY PT
B-10
HWY 2
LAND
N
1
2
3
4
5
6

Figure V-19 Isarthermal Map (Night) - Middle Branch, Baltimore Harbor

B-10 (Day)--A light gray wastewater was being discharged into the Harbor waters at this location [Figure V-13]. A pond on shore adjacent to the discharge contained wastewater identical in color to that of the discharge. This discharge was from Outfall 001 of the General Electric Company with a reported flow rate of 710 m^3/day (0.188 mgd) of process water.

B-10 (Night)--The thermal properties of the discharge were no different from the receiving water which was quite warm at the time of this mission as shown in Figure V-18. The relative temperatures of this area are presented in Figure V-19.

B-11 (Day)--General Electric Outfall 002 did not appear to be active at the time of flight [Figure V-13]. It has a reported daily flow rate of only 20 m^3/day (5,000 gpd) with a summertime temperature of 60°C (140°F). No thermal field was present.

B-11 (Night)--The presence of this individual outfall could not be determined from the thermal data. If active at the time of this mission, it most probably made a significant contribution to the large thermal field present in this general area [Figure V-18].

B-12 (Day/Night)--The airborne data contained no indications that this outfall (General Electric Outfall 003) was active at the time of flight [Figure V-13]. It reportedly has a flow rate of 230 m^3/day (0.06 mgd) at a temperature of 30°C (86°F).

B-13 (Day/Night)--General Electric Outfall 005, which has a reported flow rate and discharge temperature of 3.8 m^3/day (1,000 gpd) and 29°C (85°F), respectively, presented no indications of being active at the time of either mission.

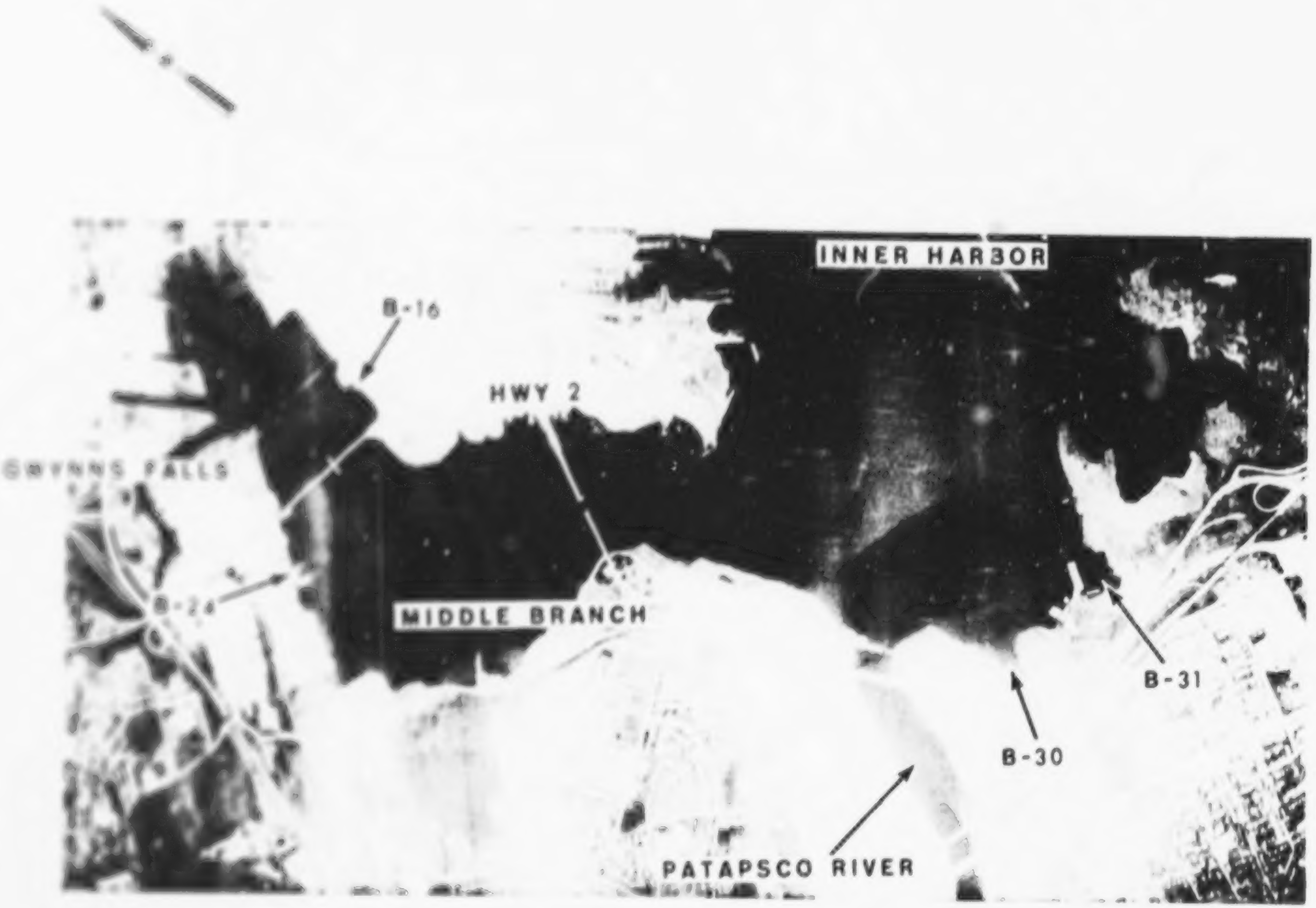
INNER HARBOR
B-16
HWY 2
GWYNNS FALLS
B-24
MIDDLE BRANCH
B-31
B-30
PATAPSCO RIVER

Figure V-20 Thermal Map (Day) - Middle Branch

B-14 (Day)--A reddish-brown substance was found in the near-surface waters at the end and along the west side of this dock.

B-15 (Day)--A small amount of dark brown wastewater was entering the Middle Branch from this location. The water source was essentially surface runoff. No plant growth was physically located in the paths connecting this area and the receiving water.

B-16 (Day)--A small thermal discharge and resultant field were recorded at this location [Figure V-20]. There was no significant increase in temperature of the receiving water in this general area.

B-16 (Night)--The effects of this discharge and resultant thermal field were much more pronounced during the night mission as shown in Figure V-18. The temperature difference between the surface water at the discharge point and the receiving water was estimated to be 3 to 4°C (5 to 7°F). This discharge originated from within the Agriculture Division, Allied Chemical Corporation. According to the permit application this discharge had a flow rate of 1,514 m^3/day (0.4 mgd) with a summertime discharge temperature of 29°C (84°F).

B-17 (Night)--The presence of a cool area (1 to 2°C cooler than ambient if it were water) was recorded at this position along the pipeline as shown in Figure V-18. This plume was coincident with the series of right angle bends in the pipeline.

B-18 (Night)--Water whose temperature was slightly warmer than the receiving water was entering the upper Middle Branch at the location marked by "a". Warm-water indications were also recorded at locations "b" and "c" [Figure V-18], although no sources were evident.

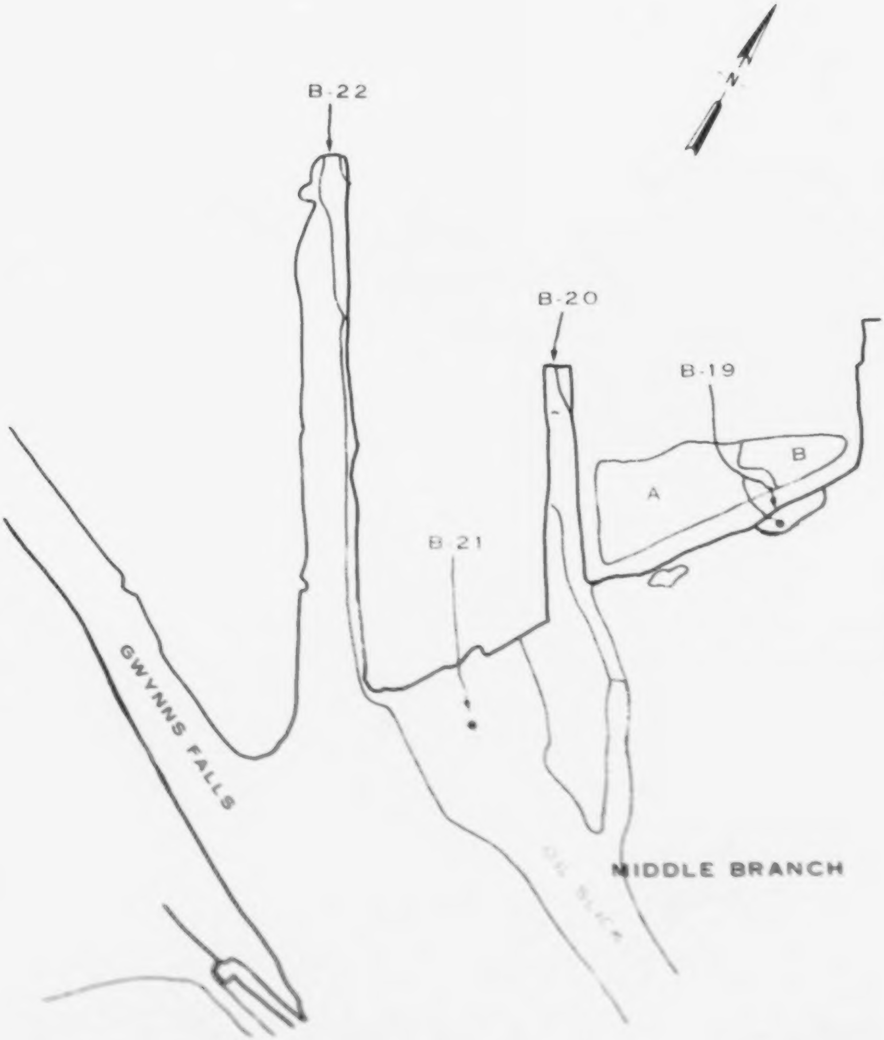
N
B-22
B-20
B-19
B
A
B-21
GWYNNS FALLS
MIDDLE BRANCH
OIL SLICK

Figure V-21 Detailed Observations - West Shore, Upper Middle Branch

B-19 (Day)--This asymmetric, triangular shaped pond contained a dark gray wastewater in the area labeled "A" and a dark yellow-brown wastewater in that labeled "B" [Figure V-21]. The gray substance was being discharged to the Middle Branch creating a plume of heavy discoloration as shown.

B-19 (Night)--A substance was mixed with or floating on the surface waters of the Harbor, coincident with this point of discharge and extending nearly across the waterway as seen through the dark gray areas in Figure V-18.

B-20 (Day)--A light gray wastewater was being discharged through this canal into the Harbor waters [Figure V-21]. The effluent contained some oil. There was a rather large oil slick consisting of about 480 liters (127 gal.) of refined oil. The source of the wastewater in the canal appeared to be a storm drain type of structure. Other sources of oil were not readily visile in the airborne data.

B-21 (Day)--A dredgig operation was in progress at the time of flight [Figure V-20]. Thre was some increase in turbidity in the water.

B-22 (Day)--An orang-brown wastewater was being discharged into the canal from a structur resembling the opening of a storm sewer. There were no thermal incations associated with the effluent. The Koppers Company, Inc. reprtedly discharges 53 m^3/day (14,000 gpd) of rinse water from an intenal metal fabrication process. This discharge may have contributed to e discoloration observed in the canal.

B-23 (Night)--A themal discharge and resultant thermal field were recorded at the locationsouth of and adjacent to the railroad bridge

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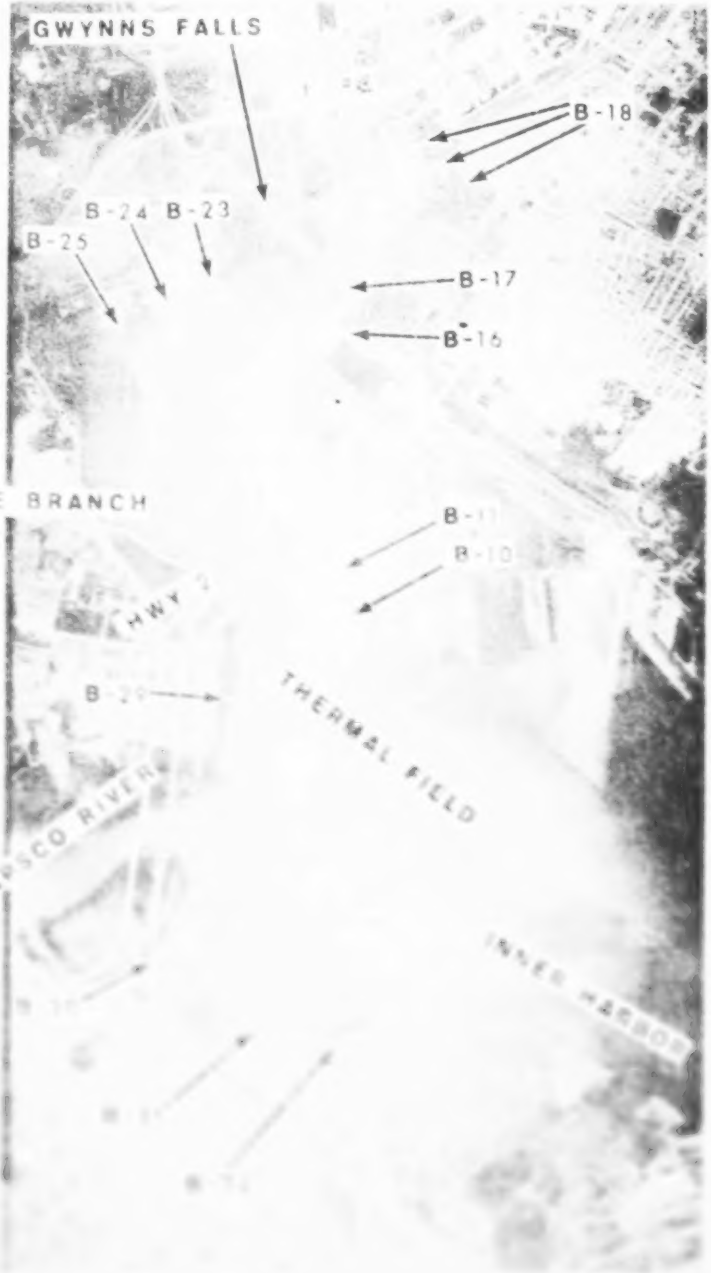

GWYNNS FALLS
B-18
B-24
B-23
B-25
B-17
B-16
MIDDLE BRANCH
B-11
B-10
HWY 2
B-29
THERMAL FIELD
PATAPSCO RIVER
INNER HARBOR

Figure V-10 Thermal Map (Night) - Middle Branch and Upper Inner Harbor

[Figure V-13]. The temperature difference between the surface water coincident with this discharge and the Middle Branch receiving water was estimated to be 2 to 3°C (4 to 5°F). The Westport Electric Generating Station has two cooling water discharges in this location with reported flow rates and discharge temperatures of 572,000 m^3/day (151 mgd) and 31°C (87°F) for Outfall 001 and 19,000 m^3/day (4.9 mgd) and 33°C (91°F) for Outfall 004.

B-24 (Day)--A thermal discharge was recorded in the area of the dock facility. The resultant thermal field is shown in Figure V-20. The approximate position of the discharge is plotted in Figure V-22. There was also an oil slick adjacent to the discharge containing 10 liters (3 gal.) of oil.

B-24 (Night)--The effects of this thermal discharge were far more prominent during the night flight. The thermal field extended 900 m (2,950 ft) from shore out into the Middle Branch waters [Figure V-18]. The temperature difference between the warmest waters within the thermal field and the background Middle Branch waters was estimated to be 2 to 3°C (4 to 5°F). The Westport Electric Generating Stations' Outfalls 002, 003, 005, and 006 are located along this section of shoreline. Reported cooling water flow rates and discharge temperatures are as follows:

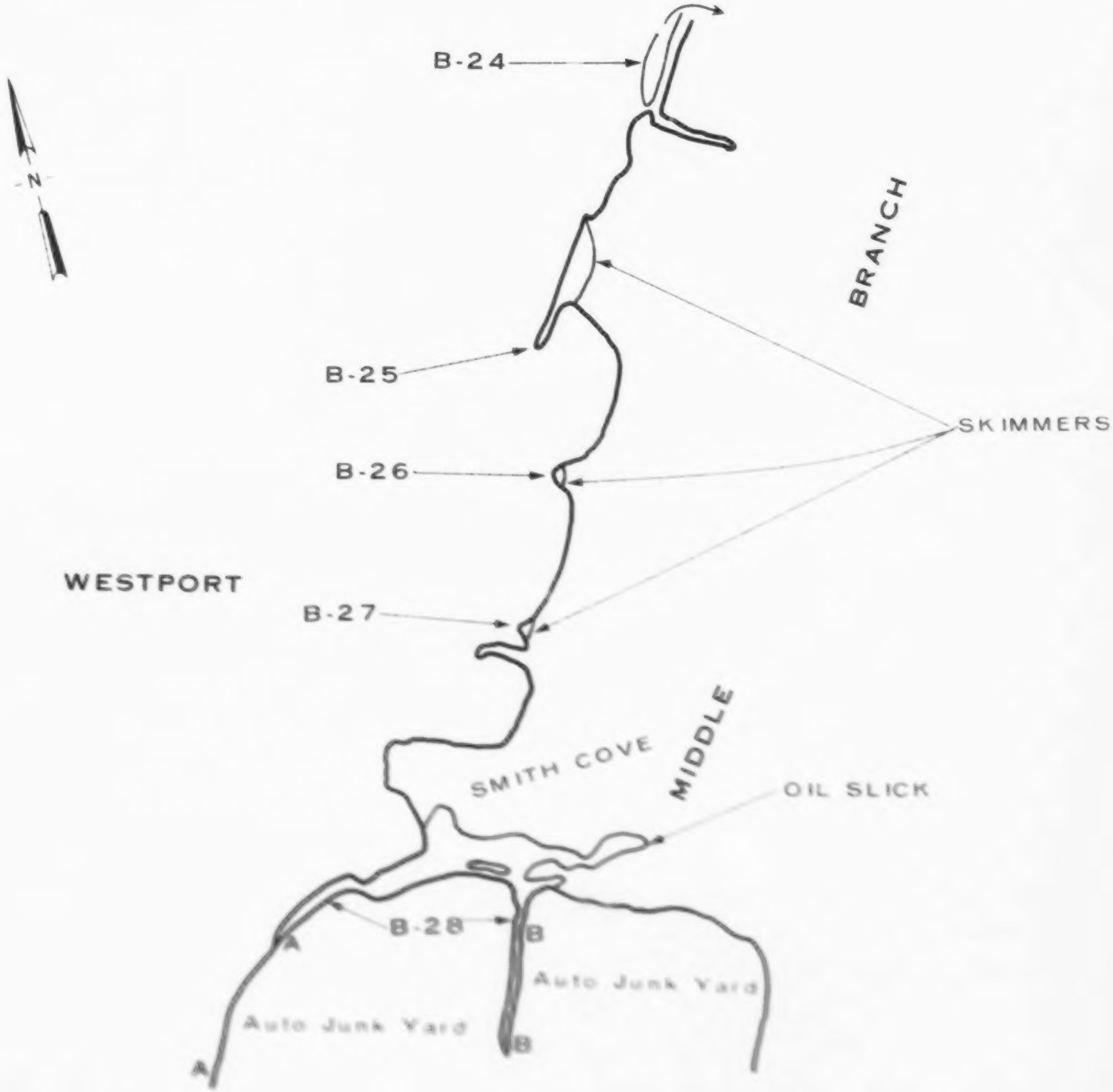

B-24
N
BRANCH
B-25
SKIMMERS
B-26
WESTPORT
B-27
MIDDLE
SMITH COVE
OIL SLICK
B-28
A
A
B
B
Auto Junk Yard
Auto Junk Yard

Figure V-22 Detailed Observations - West Shore, Lower Middle Branch

Outfall	Flow Rate		Temperature	
	(m^3/day)	(mgd)	(°C)	(°F)
002	511,000	135	31	87
003	432,000	114	31	87
005	66	0.02	31	88
006	265	0.07	21	70

B-25 (Day)--A light gray wastewater was being discharged from under a building through a small canal and into the Middle Branch waters at this location. The effluent was slightly warmer than the receiving waters [Figure V-20]. As shown in Figure V-22, there was a skimmer in place across the discharge opening into the receiving waters. This discharge is within the general vicinity of the Carr-Lowrey Company.

B-25 (Night)--This discharge was slightly cooler than the B-24 thermal field as shown in Figure V-18.

B-26 (Day)--A wastewater originating from a junk pile was backing into the Middle Branch waters from the shore location shown in Figure V-22. A skimmer was in position across this area retaining floating materials.

B-27 (Day)--A skimmer was retaining a moderate amount of solid waste materials at this location [Figure V-22].

B-28 (Day)--Oil was leaching into Smith Cove from two locations (Marked A and B) within a large automobile junkyard. The resultant oil slick contained about 22 liters (7 gal.) of oil.

B-29 (Day)--A light gray discoloration in the water appeared to be coming from this shore position [Figure V-13]. There was a great deal of rubbish on shore which precluded the positive identification of an outfall.

B-29 (Night)--A warm spot along shore was also recorded at this position as shown in Figure V-18.

B-30 (Day)--A thermal field slightly warmer than the Patapsco River water was located in this cove [Figure V-20].

B-30 (Night)--The thermal field was also present during this flight as shown in Figure V-18.

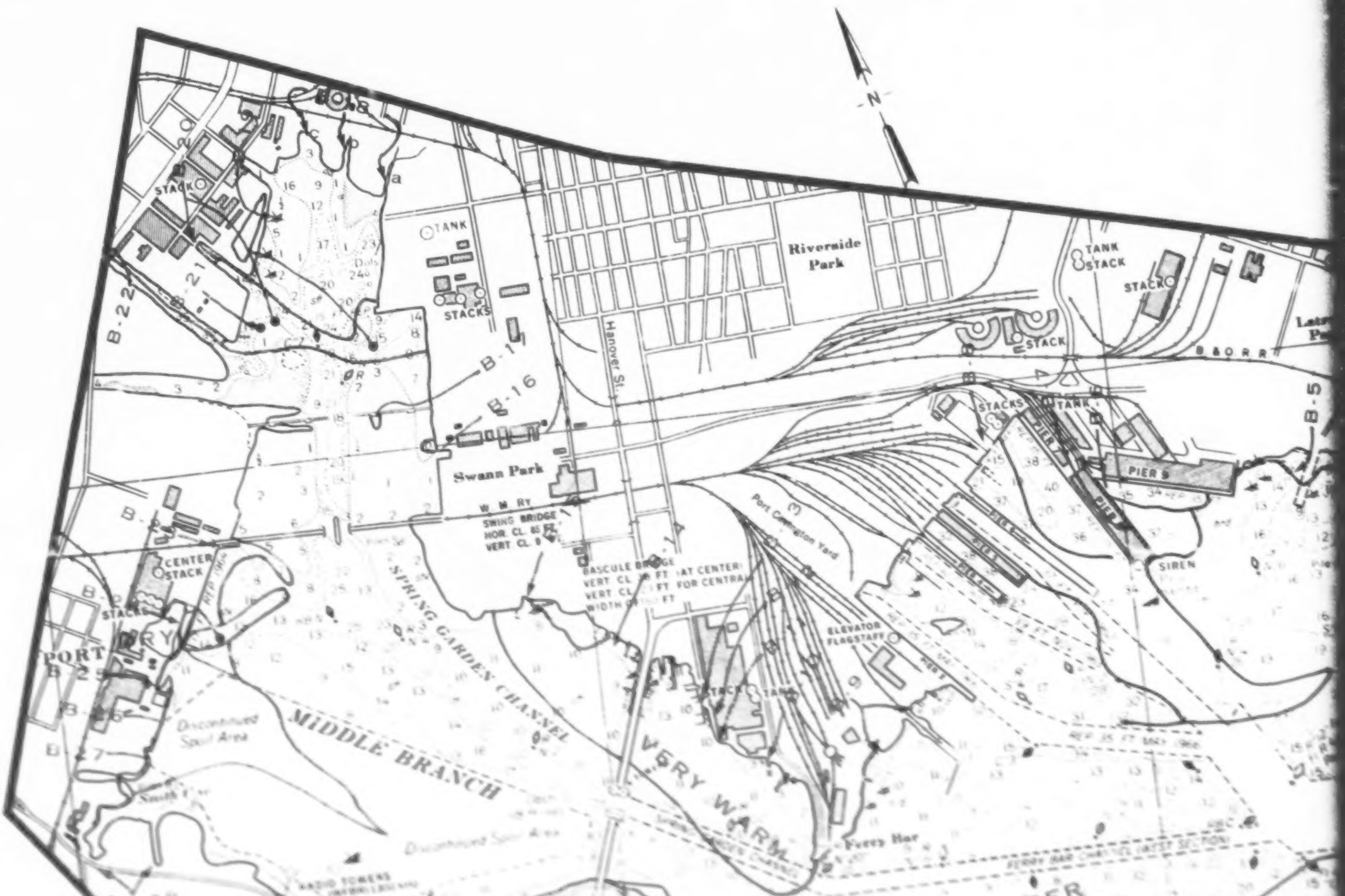
B-31 (Night)--This rectangular shaped area was significantly hotter than the ambient Inner Harbor water as indicated in Figure V-18. Comparison of this area in Figures V-18 and V-20 show the vivid contrast in surface water temperature.

B-32 (Night)--A large warm thermal field was recorded in this area. It is sketched on Figure V-13 and shown on the infrared thermal map [Figure V-18].

B-33 (Day)--A dark brown substance or discoloration in the water was recorded in and around an old dry-dock area. It may have been a leachate. It was not brown algae.

B-34 (Night)--The surface waters in this embayment were 2 to 3°C (4 to 5°F) warmer than the background (dark gray) waters in the Inner Harbor.

B-35 (Day)--Three oil slicks that contained about 19 liters (5 gal.) of refined oil were recorded in and around this dock area. The area to the south of the dashed line [Figure V-13] was not covered photographically by the day mission. Maryland Shipbuilding and Drydock Company reported four outfalls discharging cooling water, boiler blowdown and sludge-tank wastewater to the Harbor in this immediate vicinity.


N
Riverside Park
TANK
STACKS
STACK
Hanover St.
Swann Park
B & O R R
TANK
STACK
STACKS
TANK
PIER 9
SIREN
B-5
B-22
B-21
B-17
B-16
B-8
CENTER STACK
STACKS
PORT
DRY
B-25
B-26
B-27
Discontinued Spoil Area
W M RY SWING BRIDGE HOR. CL. 85 FT. VERT. CL. 9 FT.
BASCULE BRIDGE
SPRING GARDEN CHANNEL
MIDDLE BRANCH
Port Covington Yard
ELEVATOR FLAGSTAFF
STACK
TANK
VERY WARM
Ferry Bar
RADIO TOWERS
Discontinued Spoil Area
B-28
WARM WATER
COOL TURBID WATER
YELLOW-BROWN
Cherry Hill
B-29
B-32

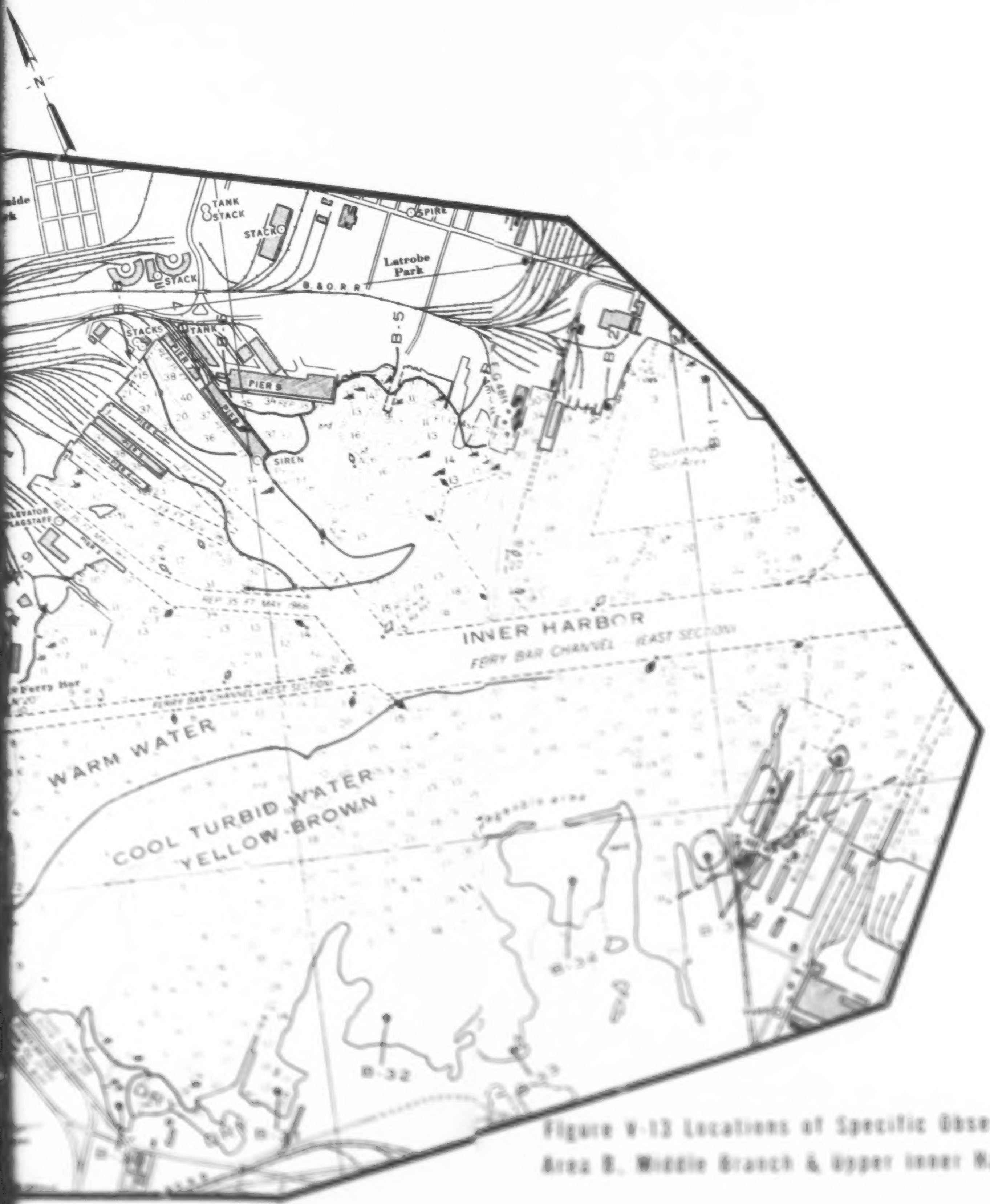

N
TANK
STACK
SPIRE
Latrobe Park
STACKS
B. & O. R.R.
PIER 5
PIER
SIREN
ELEVATOR
FLAGSTAFF
B-5
B-2
B-1
Discontinued Spoil Area
REP 35 FT MAY 1966
INNER HARBOR
FERRY BAR CHANNEL - (EAST SECTION)
FERRY BAR CHANNEL (WEST SECTION)
WARM WATER
COOL TURBID WATER
YELLOW-BROWN
B-3
B-34
B-32
B-33

Figure V-13 Locations of Specific Observations - Area B, Middle Branch & Upper Inner Harbor

LOWER INNER HARBOR AND CURTIS BAY (AREA C)

This section of the study area covers a major portion of Inner Harbor between the Harbor Tunnel and the Outer Harbor Crossing [Figure V-1]. Excluding Curtis Bay, the area is about 5 km (3 mi) long and about 2.4 km (1.5 mi) wide. Fort McHenry Channel, about 13 m (42 ft) deep, traverses the length of the Harbor. Water depths in the middle half of the Harbor outside the Channel average 6 to 10 m (20 to 32 ft). Disposal of spoil has produced shallower areas near shore but depths exceeding 2 m (6 ft) are common.

Colgate Creek, a small tidal stream, enters the Harbor from the north. A channel dredged to 11 m (34 ft) connects Dundalk Marine Terminal, located at the mouth of Colgate Creek, to the Fort McHenry Channel.

Curtis Bay and Curtis Creek form a major arm of the Harbor comparable in size to Northwest Branch [see Figure V-23, a foldout located at the end of the Area C discussion, for more detail]. The portion of the Bay and Creek included in the study area extends about 5 km (3 mi) south of the Harbor to Arundel Cove. The Curtis Bay Channel, 13 m (42 ft) deep, and the Curtis Creek Channel, ranging from 6 to 10 m (20 to 32 ft) deep, produce deep-water conditions in much of this tributary area.

A major portion of the freshwater inflow to the Harbor enters Areas A and B upstream from the Harbor Tunnel. This inflow coupled with the significant upstream tidal prism would be expected to produce larger displacements of water on each tidal cycle than characteristic of Areas A and B.

The shorelines of Curtis Bay and Curtis Creek as well as the western and northern shorelines of this Harbor section are moderately to heavily industrialized. The eastern and southern shorelines are less developed.

General Observations

Marked differences in the color of surface waters were observed at various locations in Area C. The northern region had a yellow-gray characteristic color with only isolated patches of brown algae. Along the southern shore opposite Fort McHenry, the water contained a yellow-brown turbidity that continued into Curtis Bay beyond Wagners and Fishing Points. The waters of lower Curtis Creek and Curtis Bay from Sledds Point to Hawkins Point were dark gray-brown with the exception of Thoms Cove, discussed in the next section. The southern region of Area C contained numerous patches of brown algae.

Specific Observations

Identifying numbers for specific observations in the Curtis Bay, Curtis Creek and western and southern shoreline areas are overprinted in red on Figure V-23, a section of the U. S. Coast and Geodetic Survey Nautical Chart 545.

C-1 (Night)*--A small, pronounced cool-water plume was recorded in this dock area as shown in the night thermal map [Figure V-24] and sketched in Figure V-23.

C-2 (Night)--A small, isolated warm spot on shore resembling a small volume discharge was located here. The resultant thermal plume was also quite small. A careful inspection of Figure V-24 indicated the warm effect extended from shore toward the hot L-shaped building.

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* Indication numbers C-1 through C-4 were not covered during the day mission.

C-3 (Night)--Chevron Asphalt Company's Outfall 001 was discharging a warm effluent creating a thermal field that extended beyond the end of this dock area [Figure V-24]. The surface water temperature difference between this field and the ambient harbor waters was about 1°C (2°F). This outfall reportedly discharges process water with a flow rate of 1,360 m^3/day (0.36 mgd) and a summertime temperature of 45°C (115°F).

C-4 (Night)--A very warm thermal discharge was entering the small dock area at this point, indicated by the red arrow [Figure V-23]. The hot surface water was being retained by a skimmer or other similar device as recorded in Figure V-24 and sketched in Figure V-23. The hot water was moving past this retainer along the northwest bank (shown by arrow) creating a thermal field in the large dock area.

C-5 (Day)--The water near shore in this general area was dark brown containing significant amounts of brown algae. The water in the Harbor just out from the docks was yellow-gray and very turbid. Also, near a ship tied at this dock, a pink cohesive substance was floating on the water surface. It was definitely not aquatic plant growth. This type of indication has been recorded in other areas of the country in association with a crude oil spill. The substance was the last remaining constituent after the spill had degraded with time.

C-5 (Night)*--A thermal field was located around a ship at this dock position. The source of the warm water could not be determined. The field extended [Figure V-24] in the ebb tide direction even though

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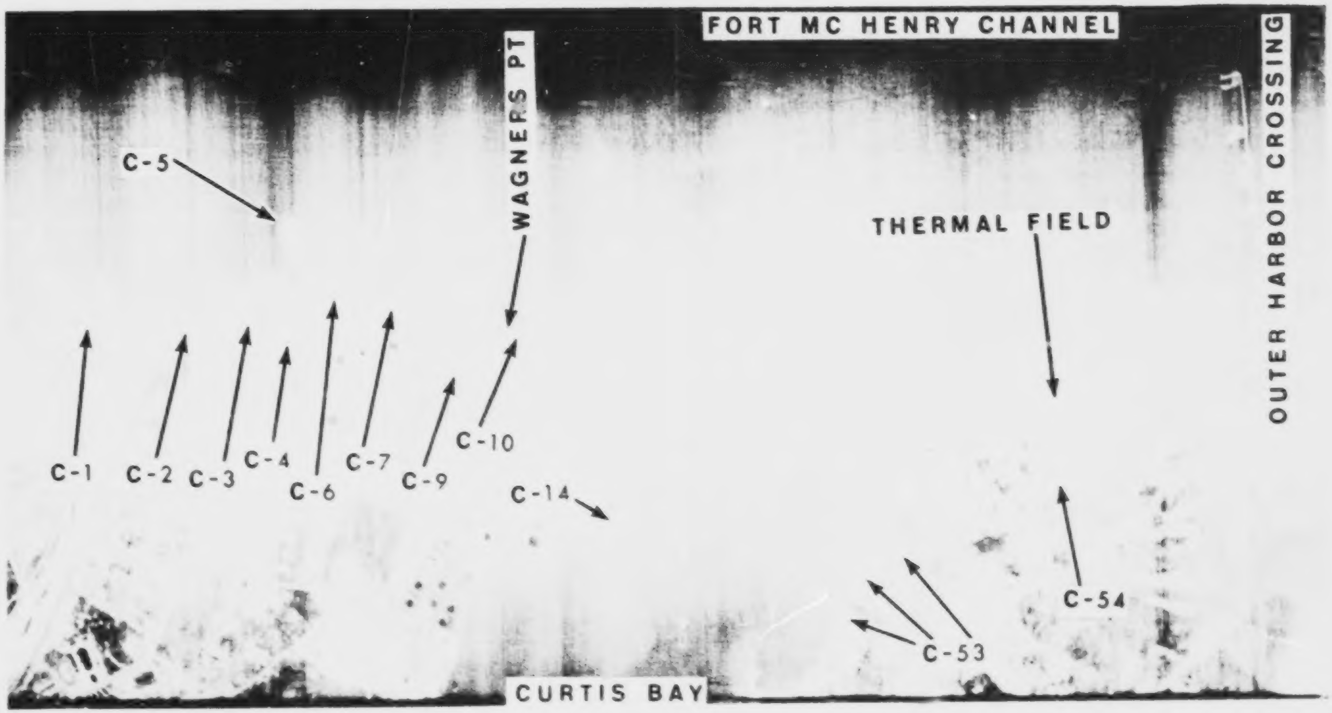
* Indications C-6, C-7 and C-9 through C-14 were not covered during the day mission.



FORT MC HENRY CHANNEL
OUTER HARBOR CROSSING
WAGNERS PT
THERMAL FIELD
C-5
C-1
C-2
C-3
C-4
C-6
C-7
C-9
C-10
C-14
C-53
C-54
CURTIS BAY

Figure V-24 Thermal Map (Night) - West Shore, Inner Harbor

the tide phase at the time of flight was well into flood condition as referenced at Fort McHenry directly across the Harbor.

C-6 (Night)--A very small thermal field was recorded at this shore position. Mobile and Shell Oil Companies reported discharges at this location consisting of only storm runoff.

C-7 (Night)--A large thermal field completely filled this area along shore as shown in Figure V-24. The source of the warm water was not readily determined. It may have been an extension of the field reported in C-4. The only known discharges in this area are from Shell Oil Company Outfalls 005, 006 and 007, reportedly discharging surface runoff only.

C-8 (Day)--The City of Baltimore Patapsco Sewage Treatment Plant [Figure V-23] had a submerged outfall at this location. The effluent was yellow-gray in color creating a plume that propagated in a southeasterly direction as sketched in Figure V-23. There were no thermal indications associated with this discharge.

C-9 (Night)--A warm thermal field nearly filled the surface water of this dock area [Figure V-24]. The source of the warm water could not be determined. The temperature difference between this field and the Harbor waters was estimated to be 1 to 2°C (2 to 4°F).

C-10 (Night)--A small isolated thermal field was located at the immediate end of the dock facility at Wagners Point [Figure V-24]. The source could not be determined from the airborne data.

C-11 (Night)--Small cool-water discharges were detected at these two shore positions as shown in Figure V-25. These two positions were reported by American Oil Company as abandoned existing outfalls.

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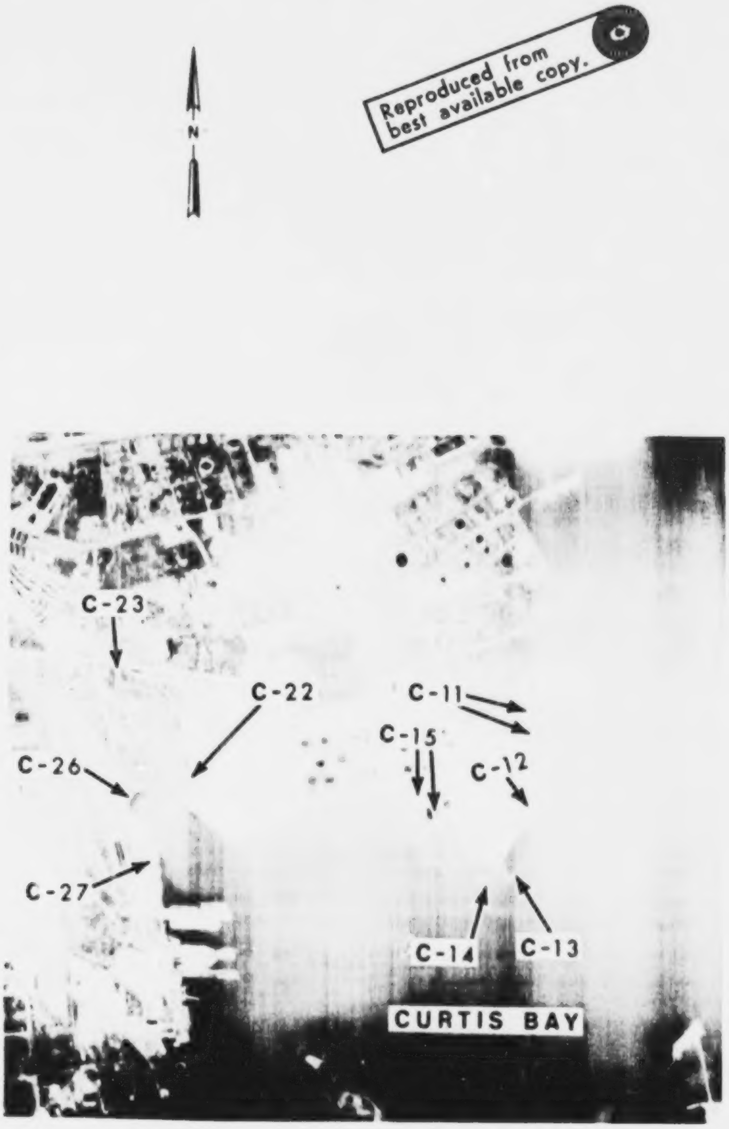
N
C-23
C-22
C-11
C-15
C-26
C-12
C-27
C-14
C-13
CURTIS BAY

Figure V-25 Thermal Map (Night) - North Shore, Curtis Bay

C-12 (Night)--A warm discharge and resulting small thermal field was recorded at this location [Figure V-25]. The temperature difference between the surface waters near the discharge and the ambient Harbor waters was estimated to be 4 to 6°C (7 to 11°F). This discharge (process water) was Outfall 001 from the American Oil Company Refinery with a reported flow rate of 3,270 m^3/day (0.864 mgd) at a summertime discharge temperature of 29°C (84°F).

C-13 (Night)--A moderately cool discharge was recorded at this shore position. American Oil Company reported a 20-cm (8-in.) outfall here but did not report waste characteristics or flow rate.

C-14 (Night)--A small moderately warm thermal field was located between these two small docks as shown in Figure V-24. In Figure V-25 (recorded about one hour later) the field had virtually disappeared. This indication appeared to be an intermittent discharge from either of two outfalls reported by the American Oil Company as abandoned existing outfalls.

C-15 (Day)--A pond containing a dark brown wastewater was located at position "a" [Figure V-23]. The pond outfall did not appear to be active at flight time. The pond at position "b" was discharging a yellow-gray wastewater. The B P Oil Corporation reported this discharge contains surface runoff with a flow rate of 7 m^3/day (1800 gpd).

C-15 (Night)--A moderately warm thermal effluent, located at shore position "a," was producing a small thermal plume along shore [Figure V-25]. The temperature difference between the thermal plume and background surface waters was estimated to be 1 to 2°C (2 to 4°F). This

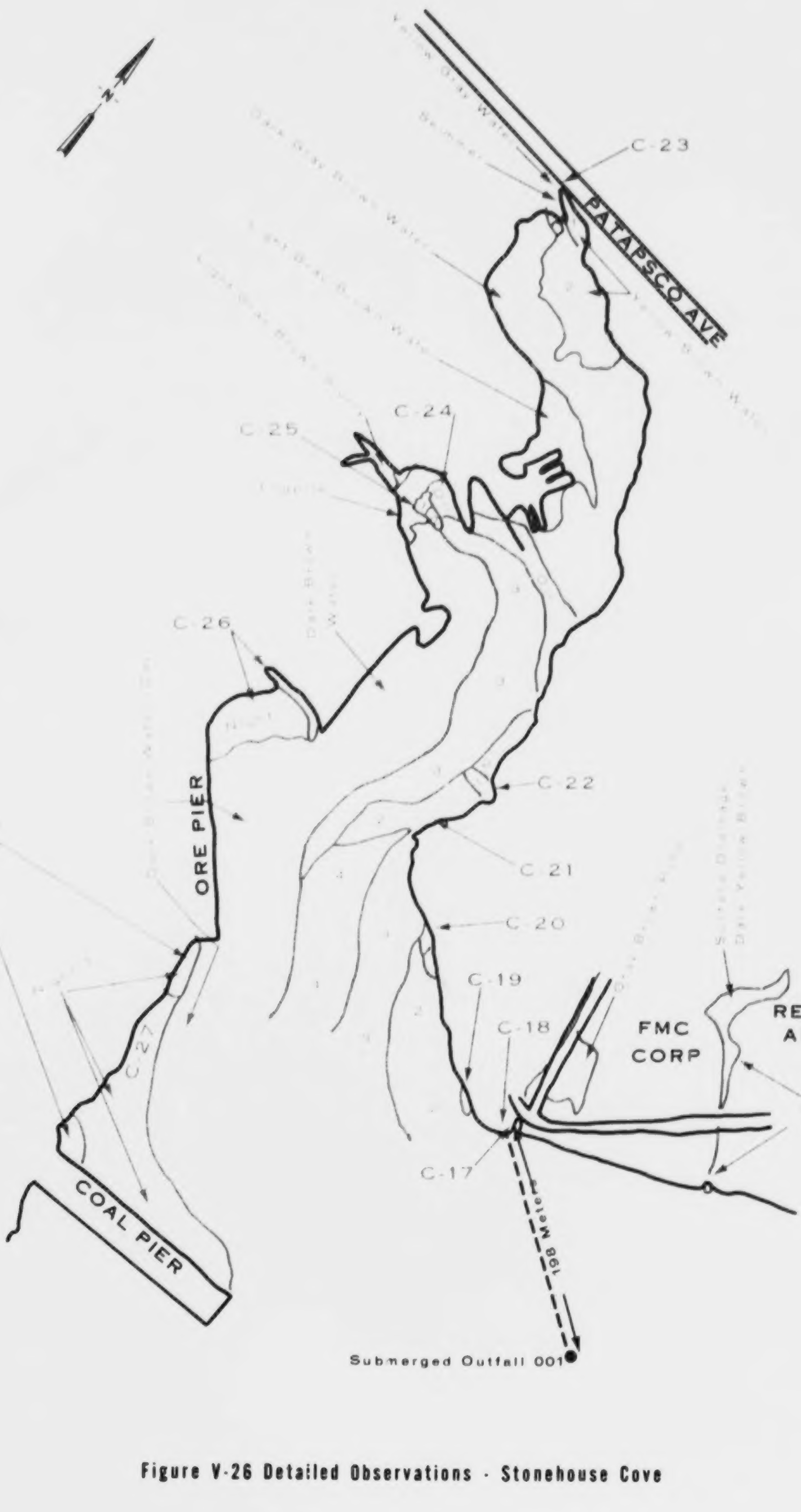
N
Yellow Gray Water
Skimmer
C-23
PATAPSCO AVE
Dark Gray Brown Water
Light Gray Brown Water
Yellow Brown Water
C-24
C-25
C-26
Dark Brown Water
ORE PIER
C-27
COAL PIER
C-22
C-21
C-20
C-19
C-18
C-17
FMC CORP
REFUSE AREA
Surface Discharge Dark Yellow Brown
C-16
198 Meters
Submerged Outfall 001

Figure V-26 Detailed Observations - Stonehouse Cove

effluent was from Texaco Oil Company's Outfall 001 reportedly discharging process wastewater and surface runoff with a flow rate of 600 m^3/day (0.16 mgd).

C-16 (Day)--A dark yellow-brown wastewater was entering Curtis Bay from this shore location [Figure V-26]. The water was traveling overland, originating from an industrial refuse area located within the FMC Corporation industrial facility.

C-17 (Day)--This poorly maintained outfall structure was not active at the time of flight. There were two ponds located across a road north of this location in the FMC facility [Figure V-26].

C-18 (Day)--FMC Corporatin's Outfall 001 did not create a visable plume during this mission. The submerged outfall extends about 198 m (650 ft) from shore [Figure V-26]. The solid line on land was the section of the pipe above ground. It measured about 25 cm (10 in.) in diameter. The FMC RAPP application indicated that this discharge (process water) had a flow rate of 9,420 m^3/day (2.49 mgd) with a summertime temperature of 30°C (86°F).

C-19 (Day)--A light yellow-brown wastewater was flowing into Stonehouse Cove at this point. The water moved overland rather than through a ditch or pipe. It created a small discolored area in the receiving water as shown in Figure V-26. This was within the FMC Corporation facility.

C-20 (Day)--A medium yellow-brown wastewater was flowing overland and into Stonehouse Cove at this point. A yellow-brown plume was recorded in the receiving water as shown in Figure V-26. The numbers

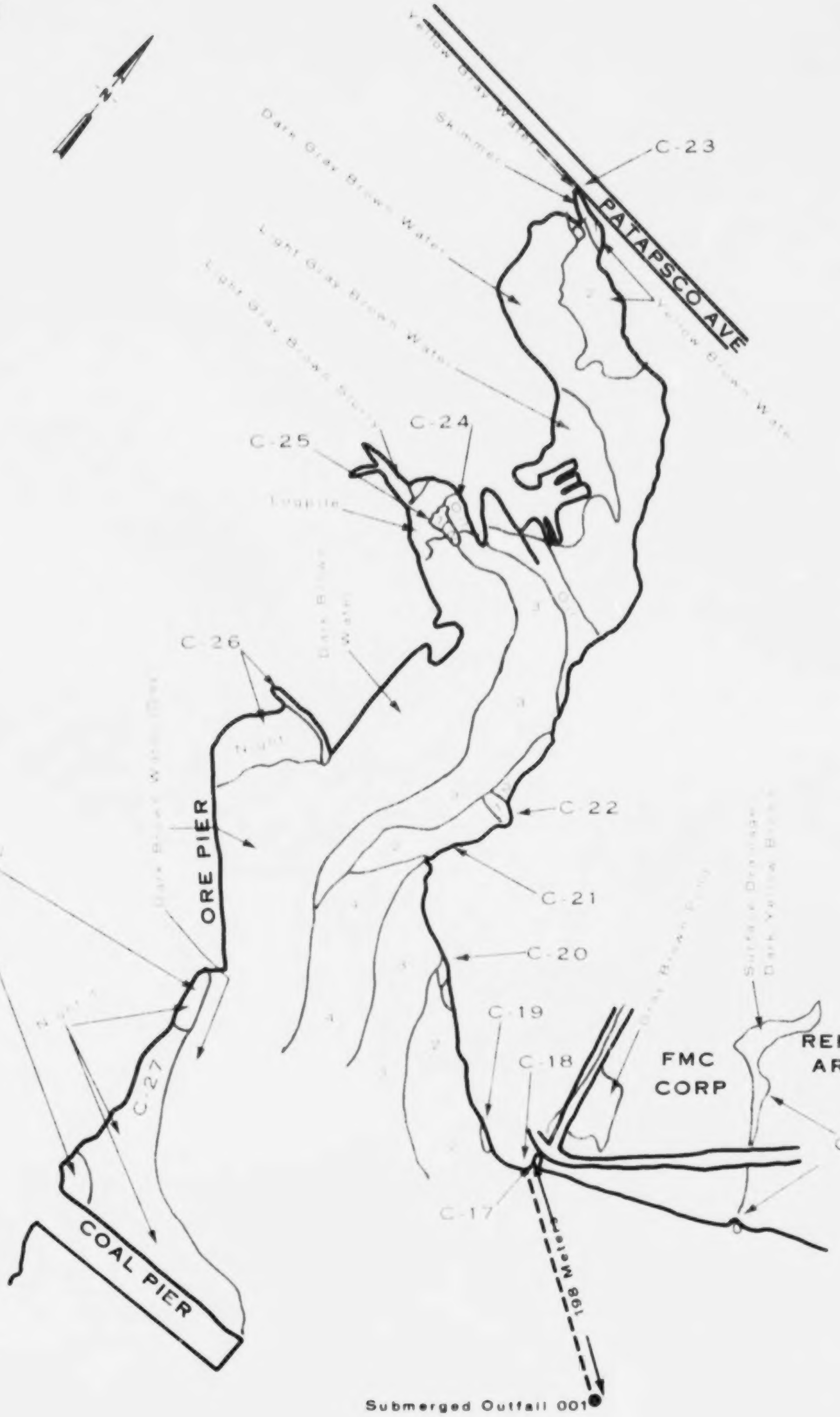
N
Yellow Gray Water
Skimmer
C-23
PATAPSCO AVE
Dark Gray Brown Water
Yellow Brown Water
Light Gray Brown Water
C-24
C-25
Dark Brown Water
C-26
Night
ORE PIER
Dark Brown Water
C-22
C-21
Night 2
Night 1
C-20
C-19
C-18
FMC CORP
REFUSE AREA
Surface Drainage
Dark Yellow Brown
C-16
C-27
C-17
COAL PIER
198 Meters
Submerged Outfall 001

Figure V-26 Detailed Observations - Stonehouse Cove

2, 3 and 4 depict the relative concentration or magnitude in the water with 2 being the greatest value. This location was within the FMC Corporation facility.

C-21 (Day)--A ditch was carrying a small amount of wastewater (surface runoff) within the FMC Corporation facility into Stonehouse Cove. The discoloration in the receiving water was too great to ascertain the effect of this discharge.

C-22 (Day)--A dense yellow-brown discharge was entering the Stonehouse Cove waters at this indentation in the shoreline [Figure V-26]. Significant discoloration was present in the receiving waters, the relative magnitudes of which are given by the areas numbered 1, 2, 3, and 4 with 1 being the greatest value. This discharge was within the FMC Corporation facility but was not included in their RAPP permit application.

C-22 (night)--A warm thermal field in the Cove originated at this location. It is the warmest area (surface water)in the Cove as seen in Figure V-25.

C-23 (Day)--A yellow-brown wastewater was flowing out of a storm drain structure adjacent to Patapsco Avenue. A surface skimmer was in place across the drain. The resultant plume of discoloration in the upper Cove waters was yellow-gray (outside the skimmer) as shown in Figure V-26. Two relative levels of discoloration are indicated by numbers 1 and 2.

C-23 (Night)--This area was characterized by a cool thermal field as shown in Figure V-27.

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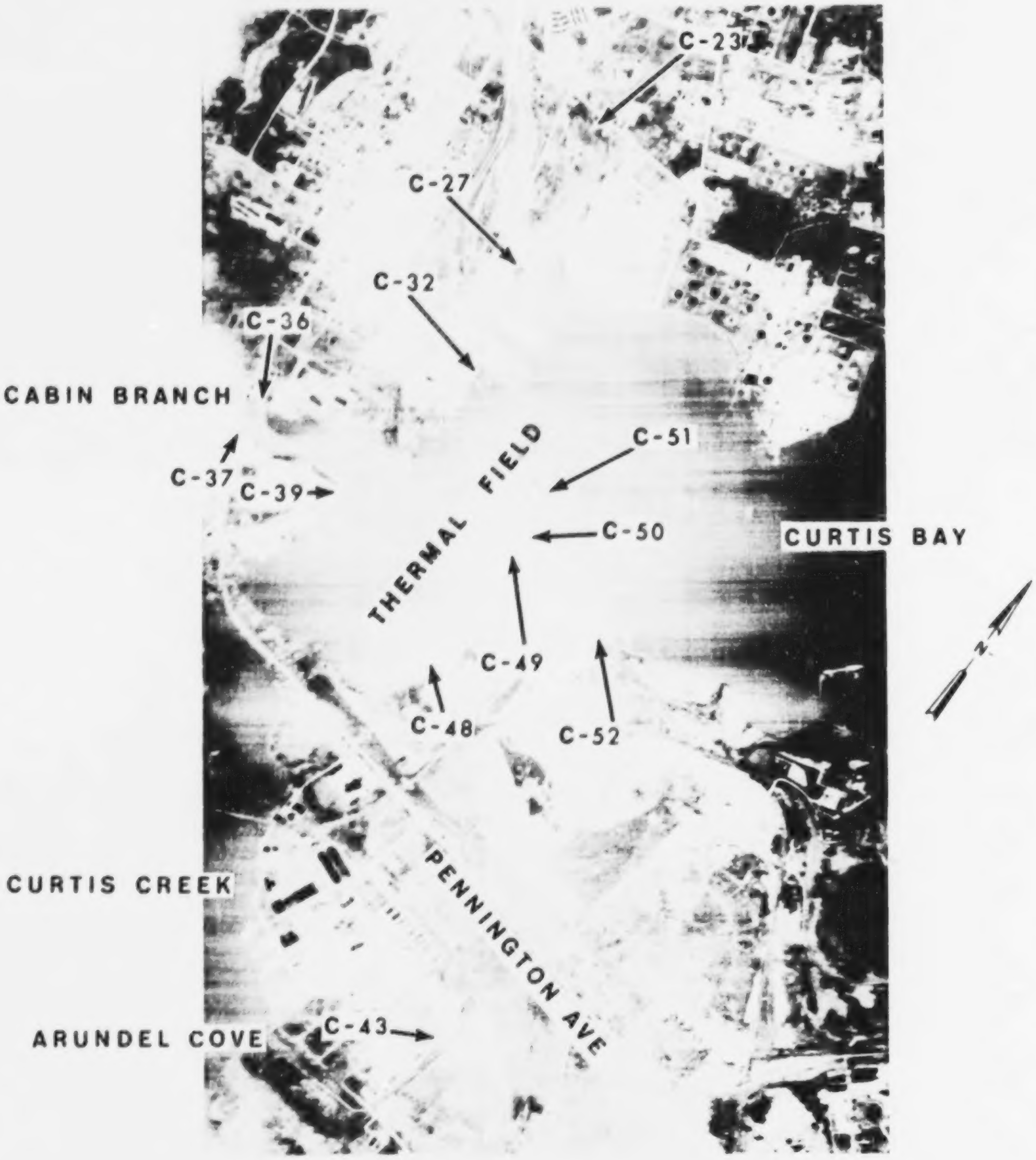
C-23
C-27
C-32
C-36
CABIN BRANCH
C-37
C-39
THERMAL FIELD
C-51
C-50
CURTIS BAY
C-49
C-48
C-52
N
CURTIS CREEK
PENNINGTON AVE
ARUNDEL COVE
C-43

Figure V-27 Thermal Map (Night) - Curtis Creek and Curtis Bay

C-24 (Day)--An oil slick containing about 30 liters (8 gal.) of refined oil, extended across the Cove at this location. The heaviest concentration appeared to be in the area indicated in Figure V-26.

C-25 (Day)--A light gray-brown wastewater closely approximating a slurry was entering the Cove from this point as detailed in Figure V-26. The relative levels of discoloration are depicted in this figure by the numbers 1, 2 and 3 with 1 being the greatest. The wastewater moved from an old refuse area through a log pile into the Cove.

C-26 (Day)--A yellow-gray wastewater was being discharged from this surface outfall [Figure V-26] into the Cove waters. A small plume of discoloration was present along shore.

C-26 (Night)--A cool thermal field was recorded at the west end of Ore Pier early in the night mission [Figures V-25 and V-26]. The field was dispersing in a southeasterly direction about one hour later during this mission.

C-27 (Night)--A rather large, cool thermal field was present along this area of shoreline. As shown in Figures V-25 and V-26, the field extended from the end of the dock called Ore Pier around the right angle to the end of Coal Pier. This indication (Night 1) was imaged early in the night flight. The cool field had nearly disappeared about one hour later as shown in Figure V-27. The cool field was present at this time only at the end of Ore Pier and in the right angle at the west end of Coal Pier (Night 2). This could be indicative of a batch discharge.

C-28 (Day)--Solid waste was located along shore and in the water of the apex of this dock area [Figure V-28]. There was only minor discoloration in the water.

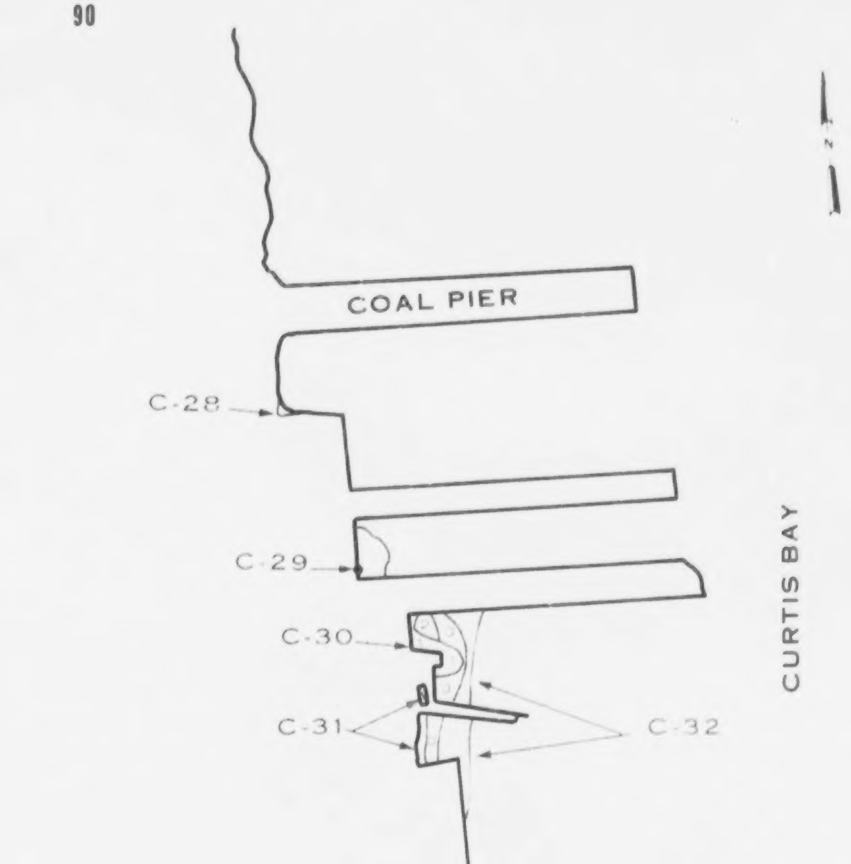
N
COAL PIER
C-28
C-29
CURTIS BAY
C-30
C-31
C-32
C-33
YELLOW GRAY
b
C-34
c
a
C-35
YELLOW BROWN
FERRY POINT
YELLOW BROWN
YELLOW GRAY

Figure V-28 Detailed Observations - West Shore, Curtis Bay

C-29 (Day)--Indications in the water at this particular location suggest the presence of a submerged outfall. A small boil was positioned near the southwestern corner of this dock area [Figure V-28]. The surface waters in the area shown were discolored a light gray.

C-30 (Day)--A dark yellow-brown discoloration was recorded in this dock area. The relative magnitude of the discoloration is shown in Figure V-28 with 1 being the greatest. This dock area was occupied by a ship demolition facility.

C-31 (Day)--Refuse along shore of the ship demolition facility was leaching into the Bay waters causing a dark yellow-brown discoloration as shown in Figure V-28.

C-32 (Night)--A moderate-sized cool thermal field nearly filled the surface waters of the dock area as shown in Figures V-27 and V-28.

C-33 (Night)--A small cool thermal field was isolated in this acute angled dock area [Figure V-28]. No active outfall was detected.

C-34 (Day)--Refuse located along shore was leaching into the Bay waters resulting in a dark brown discoloration.

C-35 (Day)--A yellow-brown wastewater was flowing in from ditch "a" as indicated in Figure V-28. A yellow-gray water was entering from ditch "b." A yellow-gray leachate was coming from ditch "c." The combined flow created a yellow-gray and a yellow-brown discoloration in Curtis Creek as sketched in Figure V-28.

C-36 (Night)--Three adjacent warm-water effluents were flowing into Cabin Branch from this shore position. The resultant thermal field extended out into Curtis Creek as shown in Figure V-27. From west to east these were Outfalls 001, 002 and 003 originating from within the

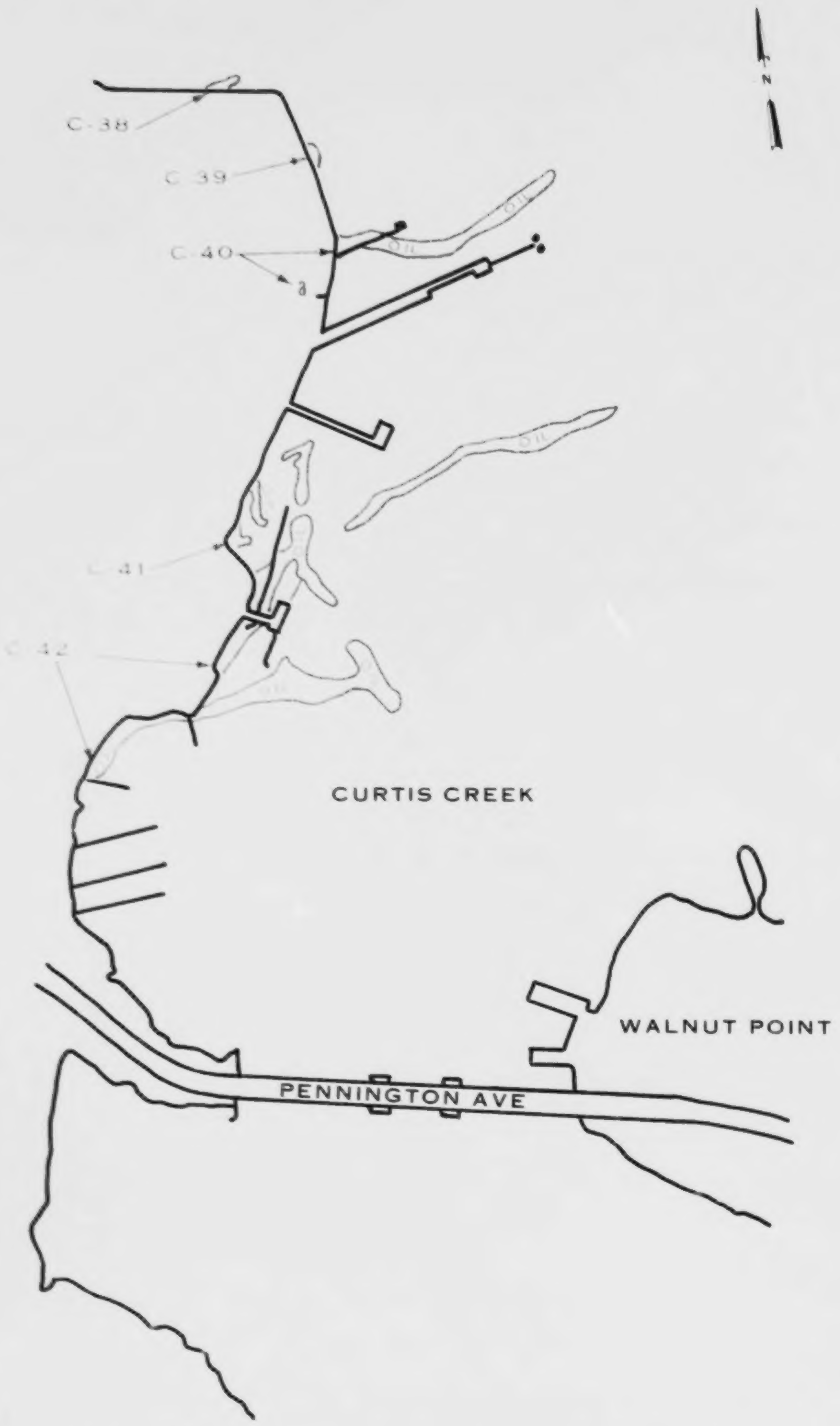
N
C-38
C-39
C-40
a
Oil
Oil
Oil
C-41
C-42
Oil
CURTIS CREEK
WALNUT POINT
PENNINGTON AVE

Figure V-29 Detailed Observations - Western Shore, Lower Curtis Creek

Olin Corporation facility which manufactures sulfuric acid. Reported outfall flow rates were as follows:

	Flow Rate	Summer Discharge Temperature
Outfall 001	18,600 m^3/day (4.9 mgd)	35°C (95°F)
Outfall 002	18,600 m^3/day (4.9 mgd)	36°C (96°F)
Outfall 003	2,700 m^3/day (0.7 mgd)	38°C (100°F)

Outfalls 001 and 002 discharge process water and Outfall 003 discharges cooling water according to the Olin RAPP application.

C-37 (Night)--A small thermal discharge was recorded at this shore position immediately to the east of the Pennington Avenue Bridge. This physical location corresponded to that of Outfall 191 within the Hess Oil and Chemical Company facility. The Company reported that this outfall discharges only 2 m^3/day (500 gpd) of surface runoff with a discharge temperature of 23°C (74°F).

C-38 (Day)--A dark yellow-brown plume was recorded along the southern Cabin Branch shore in the near vicinity of the Hess Oil Company Outfall 196 [Figure V-29]. The outfall reportedly discharges 5.3 m^3/day (1,400 gpd) of surface runoff.

C-39 (Day)--A dark yellow-brown area of discolored water containing a trace of oil was present at this shoreline position as shown in Figure V-29. This was the location of Outfall 193 of the Hess Oil Company facility that reportedly discharges 6 m^3/day (1,600 gpd) of surface runoff.

C-39 (Night)--A small thermal plume was detected at this location as shown in Figure V-27.

C-40 (Day)--A dark orange-brown plume and an oil slick extended out into Curtis Creek from the base of the dock [Figure V-29]. The oil slick

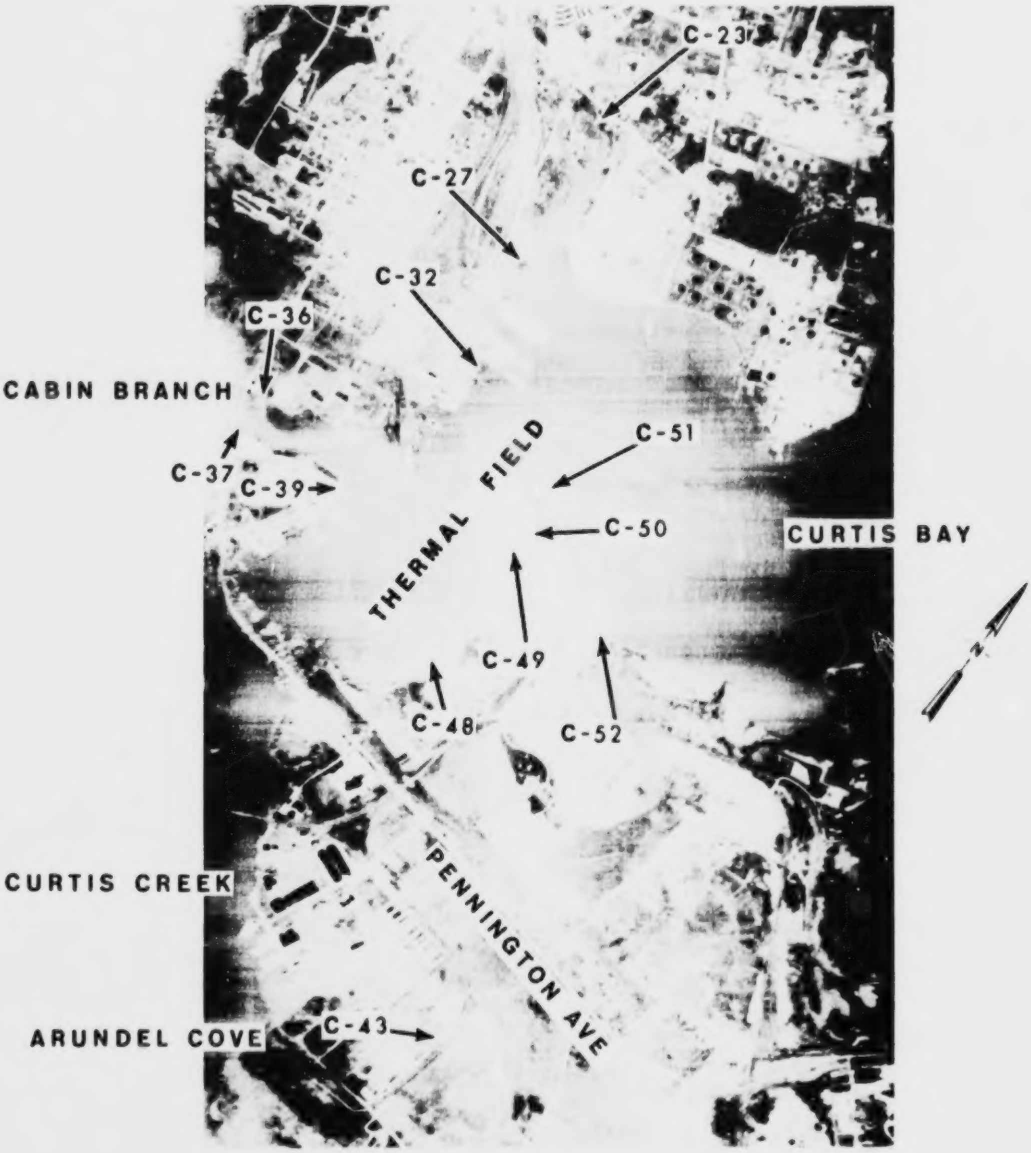
C-23
C-27
C-32
C-36
CABIN BRANCH
C-37
C-39
THERMAL FIELD
C-51
C-50
CURTIS BAY
C-49
C-48
C-52
N
CURTIS CREEK
PENNINGTON AVE
ARUNDEL COVE
C-43

Figure V-27 Thermal Map (Night) - Curtis Creek and Curtis Bay

contained about 19 liters (5 gal.) of refined oil. Hess Oil Company's Outfall 192 was about 30 m (100 ft) south of this small dock as indicated by "a" in Figure V-29. The outfall reportedly discharges 3.8 m^3/day (1,000 gpd) of surface runoff.

C-41 (Day)--A dark yellow-brown plume was recorded in this shore indentation as shown in Figure V-29. There was a structure on the shoreline at water level that may have been an outfall.

C-42 (Day)--Numerous oil slicks were recorded in this area with the heaviest concentrations along shore as indicated by the arrows in Figure V-29. The source of the oil could not readily be determined. The slicks contained about 82 liters (22 gal.) of refined oil.

C-43 (Night)--Surface waters in Arundel Cove were estimated to be 8 to 10°C (14 to 18°F) warmer than the background waters in Curtis Creek [Figure V-27]. Warm water was entering the Cove via a ditch adjacent to and along the west side of the railroad bridge. Warm water in the Cove was slowly dispersing into Curtis Creek. The source of the warm water was within the Diamond Shamrock Corporation with a reported flow rate of 2,650 m^3/day (0.7 mgd) and summertime temperature of 26°C (75°F).

C-44 (Day)--A rather dark yellow-brown wastewater was flowing into Curtis Creek at this point. There were two open tanks below ground level that contained water similar in color to that of the observed discoloration in the receiving water [Figure V-30].

C-45 (Day)--The gold-brown soil in this area of Walnut Point was backing into the creek waters.

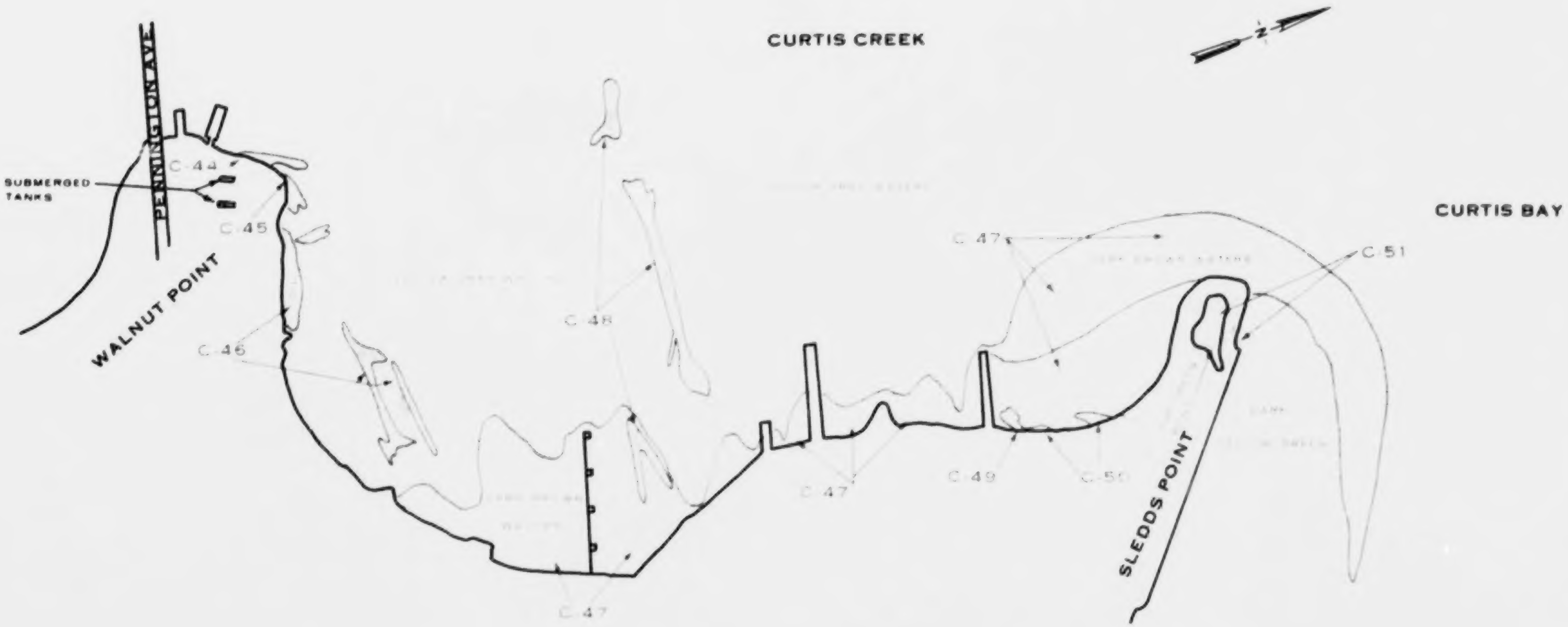
CURTIS CREEK
CURTIS BAY
N
SUBMERGED TANKS
PENNINGTON AVE
WALNUT POINT
SLEDDS POINT
C-44
C-45
C-46
C-47
C-48
C-49
C-50
C-51

Figure V-30 Detailed Observations- East Shore, Lower Curtis Creek

C-46 (Day)--Oil slicks were located along these sections of shore line as shown in Figure V-30. The slicks contained about 43 liters (11 gal.) of oil.

C-47 (Day)--The waters adjacent to shore from this dock to Sledds Point were dark brown in color [Figure V-30]. The cross-hatched areas depict the presence of chlorophyll or brown algae in a moderate concentration.

C-48 (Day)--Numerous oil slicks were recorded in this area of Curtis Creek [Figure V-30]. They collectively contained about 72 liters (19 gal.) of oil.

C-48 (Night)--There was a large thermal field along this shore as shown in Figure V-27.

C-49 (Day)--The concentration of brown algae was extremly heavy in this area [Figure V-30].

C-50 (Day)--The water along these sections of shore line was yellow-gray in color [Figure V-30]. The source could not be determined.

C-50 (Night)--A large thermal field completely filled the surface waters of this area as shown in Figure V-27. The warmest area was along this section of shore line.

C-51 (Day)--These waters of Curtis Bay were dark yellow-green [Figure V-30]. This discoloration was quite similar spectrally to the water contained in the pond on Sledds Point. The discoloration was greatest along the small section of shore indicated by arrow "a" in Figure V-30. This area is within the W. R. Grace Company facility.

C-51 (Night)--Figure V-27 shows that the Sledds Point pond water was quite warm. Also a warm discharge was located at arrow "a" of Figure V-30.

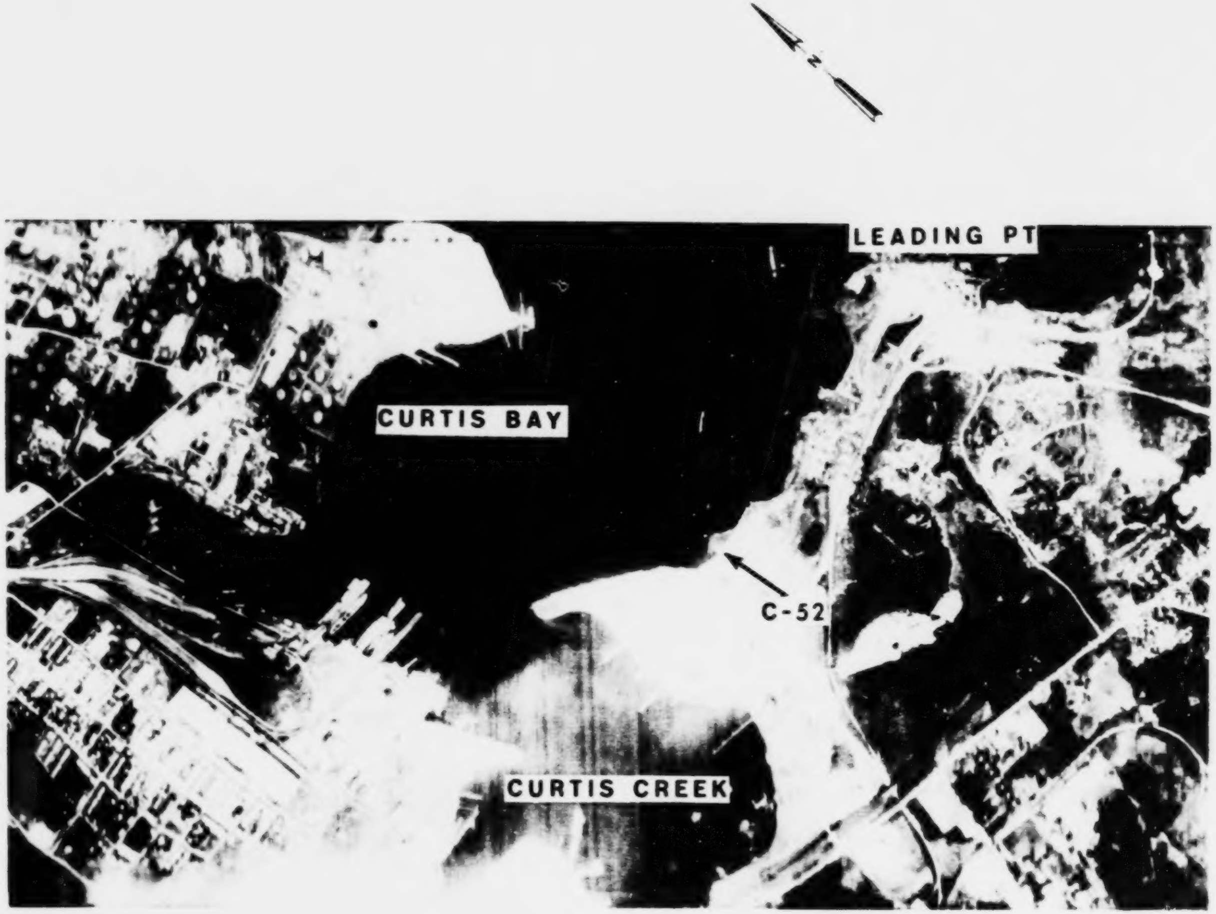
N
LEADING PT
CURTIS BAY
C-52
CURTIS CREEK

Figure V-31 Thermal Map (Day) - Curtis Bay

C-52 (Day)--A yellow-gray wastewater was flowing from this ditch into lower Curtis Bay [Figure V-23]. The discoloration was quite heavy in the immediate area. This was Outfall 001 originating from within the W. R. Grace Company. It reportedly discharges process water with a flow rate of 7,570 m^3/day (2.0 mgd). The effluent was significantly warmer than the waters of Curtis Bay as shown in Figure V-31. The temperature difference was estimated to be 7 to 8°C (13 to 14°F).

C-52 (Night)--This discharge was quite hot during the night flight as shown in Figure V-27. The temperature difference between the effluent and the background surface waters of Curtis Bay was estimated to be 7 to 8°C (13 to 14°F).

C-53 (Day)--The water in these areas was dark gray-brown in color [Figure V-23].

C-53 (Night)--The water in these areas was also slightly warmer than the ambient waters of lower Curtis Bay. A hot spot in the water indicated by the arrow labeled "a" in Figure V-23 was recorded during this flight as shown in Figure V-24. The indication resembles a submerged discharge.

C-54 (Day)--A large amount of yellow-brown wastewater was discoloring the receiving waters from Leading Point throughout Thoms Cove [Figure V-23]. The relative magnitudes of discoloration are indicated by the numbered areas with 1 being the greatest.

C-54 (Night)--The surface waters in this Cove area were 1 to 3°C (2 to 5°F) warmer than the ambient Patapsco River waters as shown in Figure V-24.

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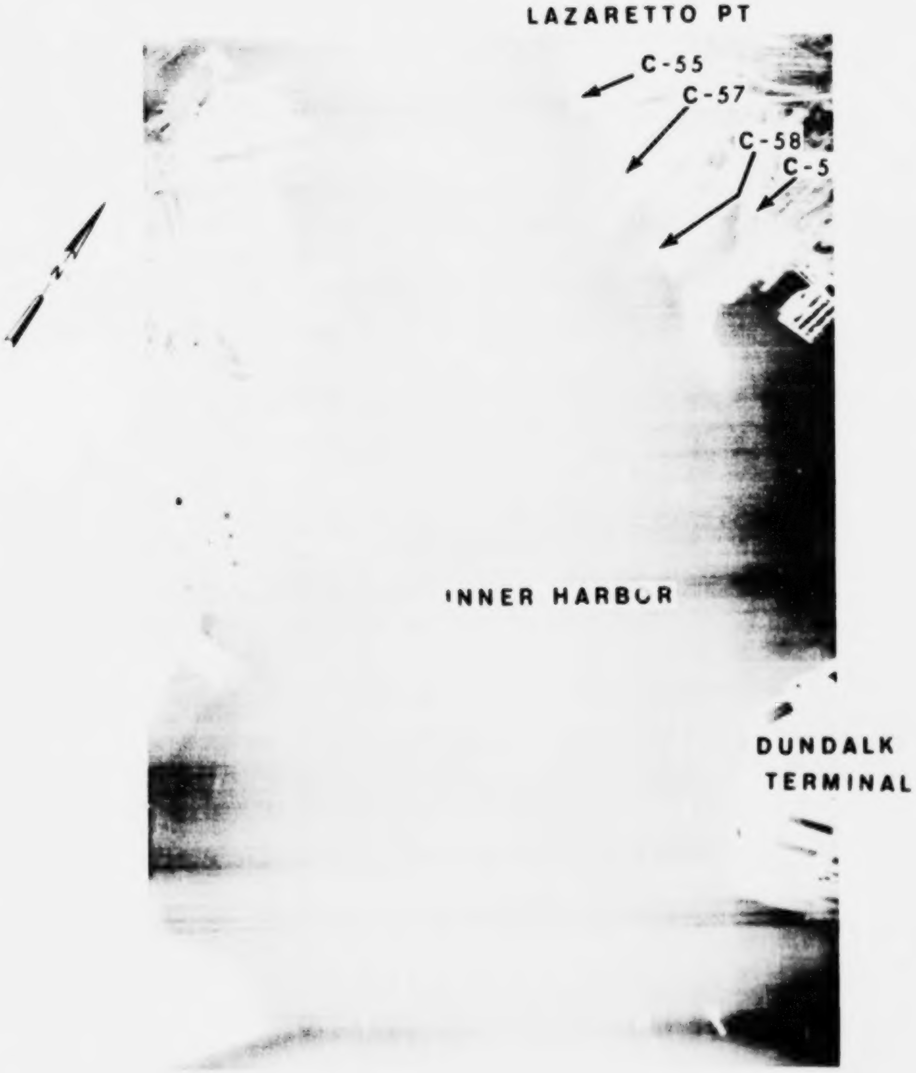
LAZARETTO PT
C-55
C-57
C-58
C-5
N
INNER HARBOR
DUNDALK
TERMINAL

Figure V-33 Thermal Map (Night) - Central Inner Harbor

The remainder of the specific observations in Area C are located on the north and east shores of the Inner Harbor. Identification numbers are overprinted in red on Figure V-32, a foldout located at the end of the Area C discussion.

C-55 (Night)--A thermal discharge was located at this position on Lazaretto Point as shown in Figure V-33. Ths discharge originated from within the Kerr McGee Chemical Corporation facility which manufactures fertilizer. The Corporation indicated that two outfalls were located here. Outfall 001 reportedly discharges 1,900 m^3/day (0.5 mgd) of process water with a summertime discharge temperature of 41°C (105°F). No data were available on Outfall 002.

C-56 (Day)--Large amounts of brown algae were located in the areas shown [Figure V-32]. The relative concentrations are given by the Numbers 1, 2 and 3 with 1 being the largest.

C-57 (Night)--A small thermal field extended from this dock area out into the River waters as shown in Figure V-33.

C-58 (Night)--A thermal field was recorded along the west side of this pier. The warmest spot in the field was at the southwest corner of the pier as shown in Figure V-33.

C-59 (Day)--A dark yellow-brown wastewater was flowing into the dock area from an open ditch [Figure V-32]. The discolored water was not dispersing appreciably but a plume did extend beyond the end of the pier.

C-59 (Night)--The effluent from this discharge was significantly warmer than the ambient river water. The thermal field did extend into the river well beyond the pier area as shown in Figure V-33. An isarthermal sketch of the field is shown in Figure V-34.

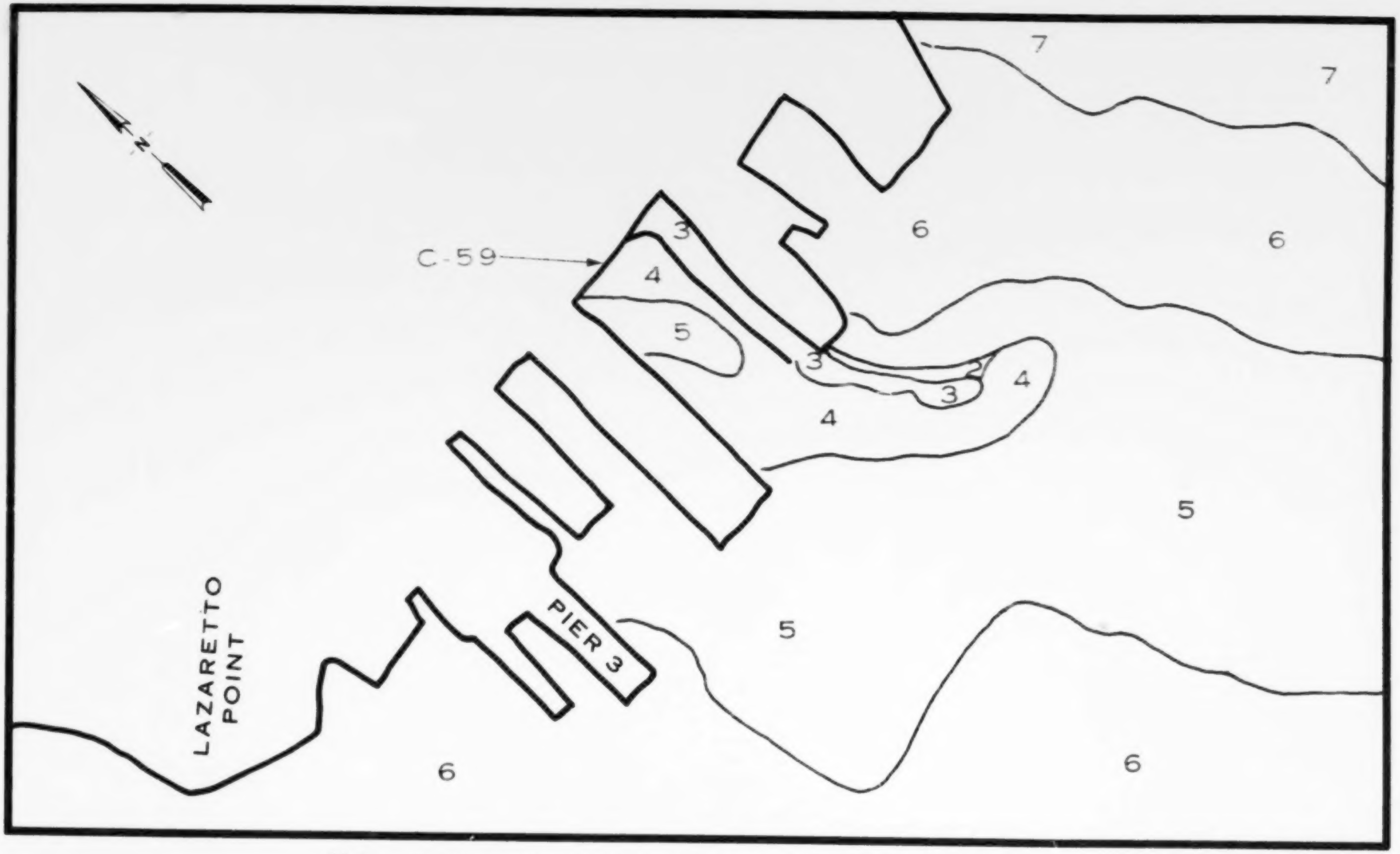
N
C-59
3
4
5
3
3
4
4
6
6
7
7
5
5
PIER 3
LAZARETTO POINT
6
6

Figure V-34 Isarthermal Map (Night) - Lazaretto Point Area

C-60 (Day)--A yellow-gray wastewater was flowing in small volume through an outfall structure positioned above water level into this dock area [Figure V-32]. The source of the water was runoff from a small area containing one large cylindrical tank.

C-61 (Day)--A brown-gray discoloration in the surface waters was located at these two dock positions. No active outfalls were recorded.

C-62 (Day)--A yellow-gray plume extended across nearly three-fourths of this dock area as sketched in Figure V-32. The head of the plume was about 25 m (80 ft) from the west side of the wide dock area.

C-63 (Day)--Wastewater was percolating out of a large light-tan pile of spoil and flowed into the Harbor creating only a small plume.

C-64 (Day)--The water in the mouth of Colgate Creek was about 1°C (2°F) warmer than the ambient waters in the Patapsco River [Figure V-35].

C-65 (Day/Night)--The effluents from the Riverside Electric (Sollers Point) Power Plant were clearly recorded during the day flight as shown in Figure V-35. The size of the resulting thermal field was considerably larger during the night flight as shown in Figure V-36 extending out into the Harbor almost to Ft. Carroll to the east of the Outer Harbor Crossing. An isarthermal sketch of this field during the night flight is shown in Figure V-37. Figure V-35 clearly indicates that Outfall 001 was the dominant source of the warm water creating the thermal field. Outfall 001 had a reported cooling-water flow rate of 1,360,000 m^3/day (360 mgd) with a summertime discharge temperature of 30°C (86°F). Outfall 002 had a cooling-water flow rate of only 2,730 m^3/day

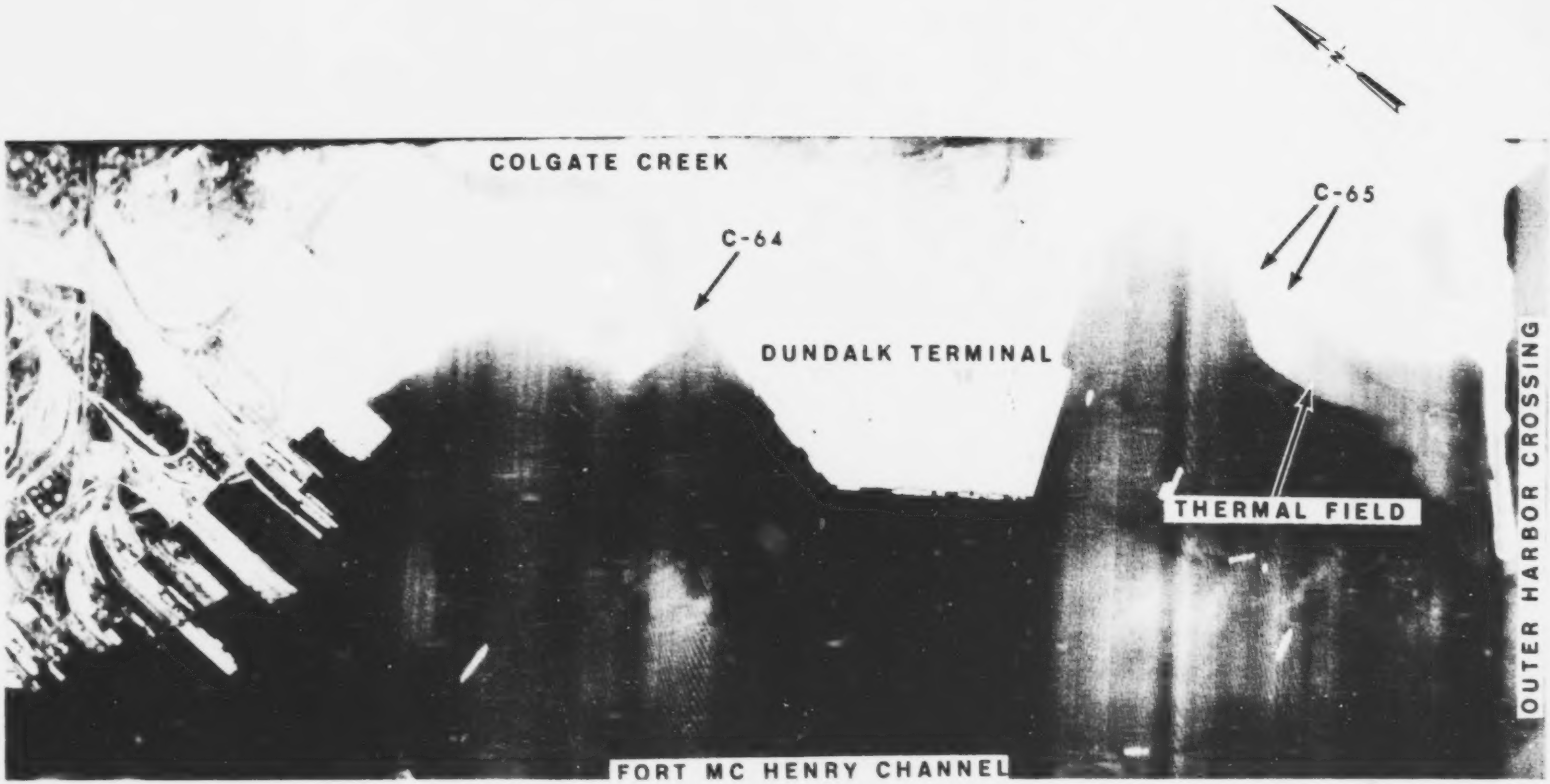
N
COLGATE CREEK
C-64
C-65
DUNDALK TERMINAL
THERMAL FIELD
OUTER HARBOR CROSSING
FORT MC HENRY CHANNEL

Figure V-35 Thermal Map (Day) - East Shore, Inner Harbor

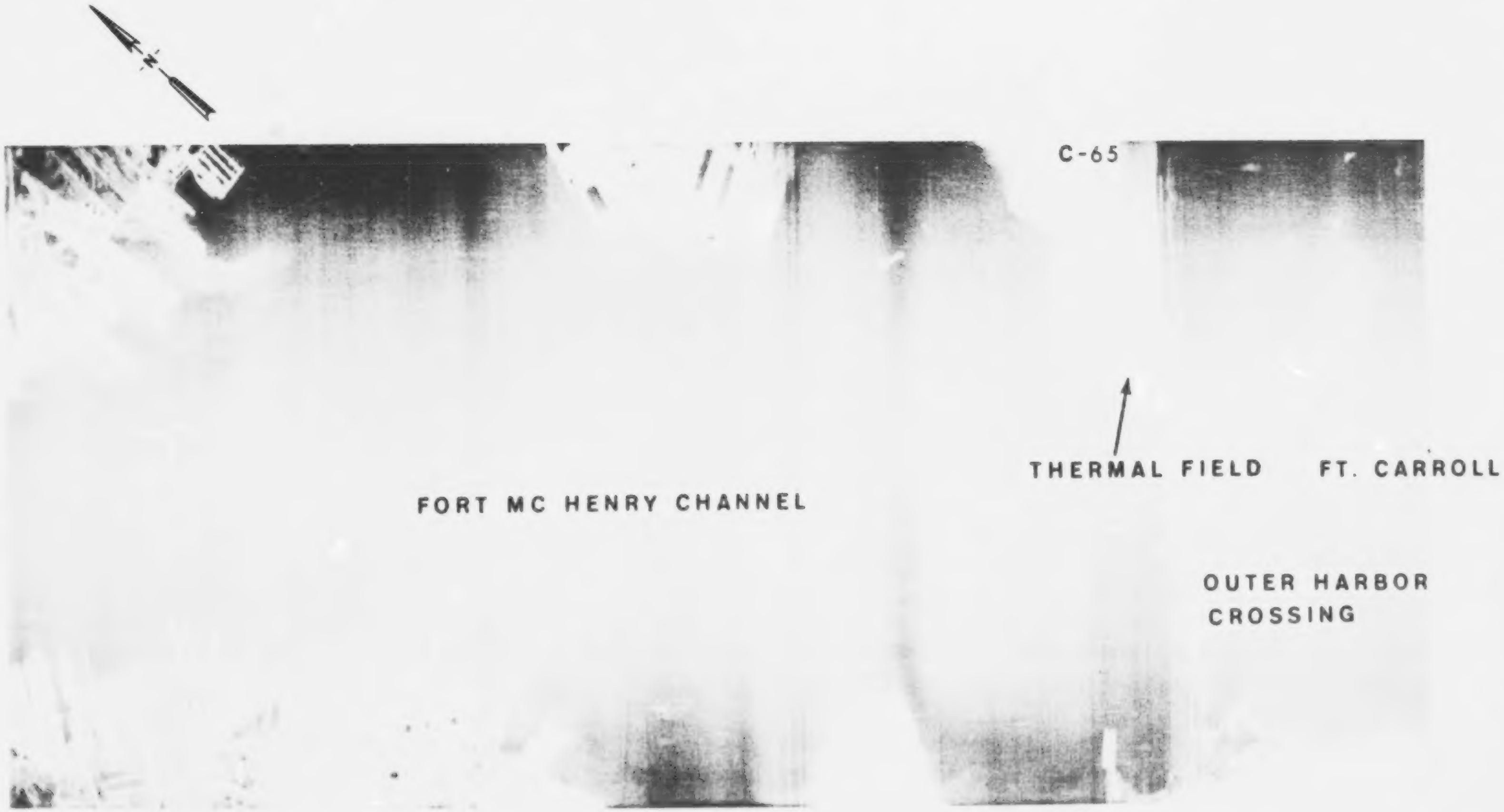
N
C-65
THERMAL FIELD
FT. CARROLL
FORT MC HENRY CHANNEL
OUTER HARBOR
CROSSING

Figure V-36 Thermal Map (Night) - Lower Inner Habor

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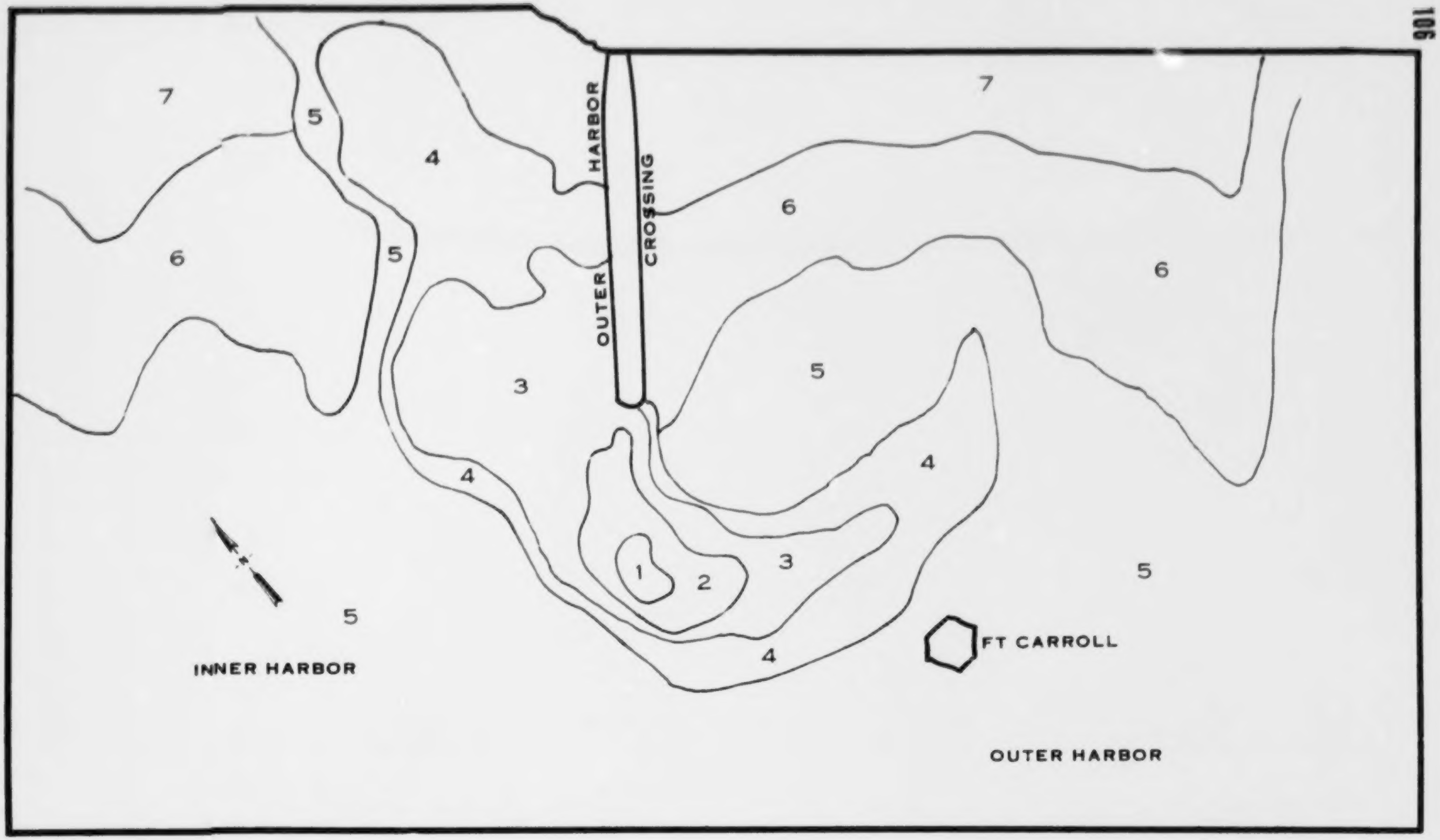

7
5
4
HARBOR
CROSSING
7
6
6
5
6
OUTER
3
5
4
4
3
1
2
5
5
4
FT CARROLL
INNER HARBOR
OUTER HARBOR

Figure V-37 Isarthermal Map (Night) - of the Sellers Point Power Plant Thermal Field

(0.72 mgd) with the same discharge temperature as Outfall 001. Considering the ratio of flow rates the thermal effects caused by 002 would be insignificant compared to those induced by 001. There was a third thermal discharge (Outfall 003) in the power plant facility having a flow rate of only 265 m^3/day (0.07 mgd) which was insignificant compared to the effects of Outfall 001.

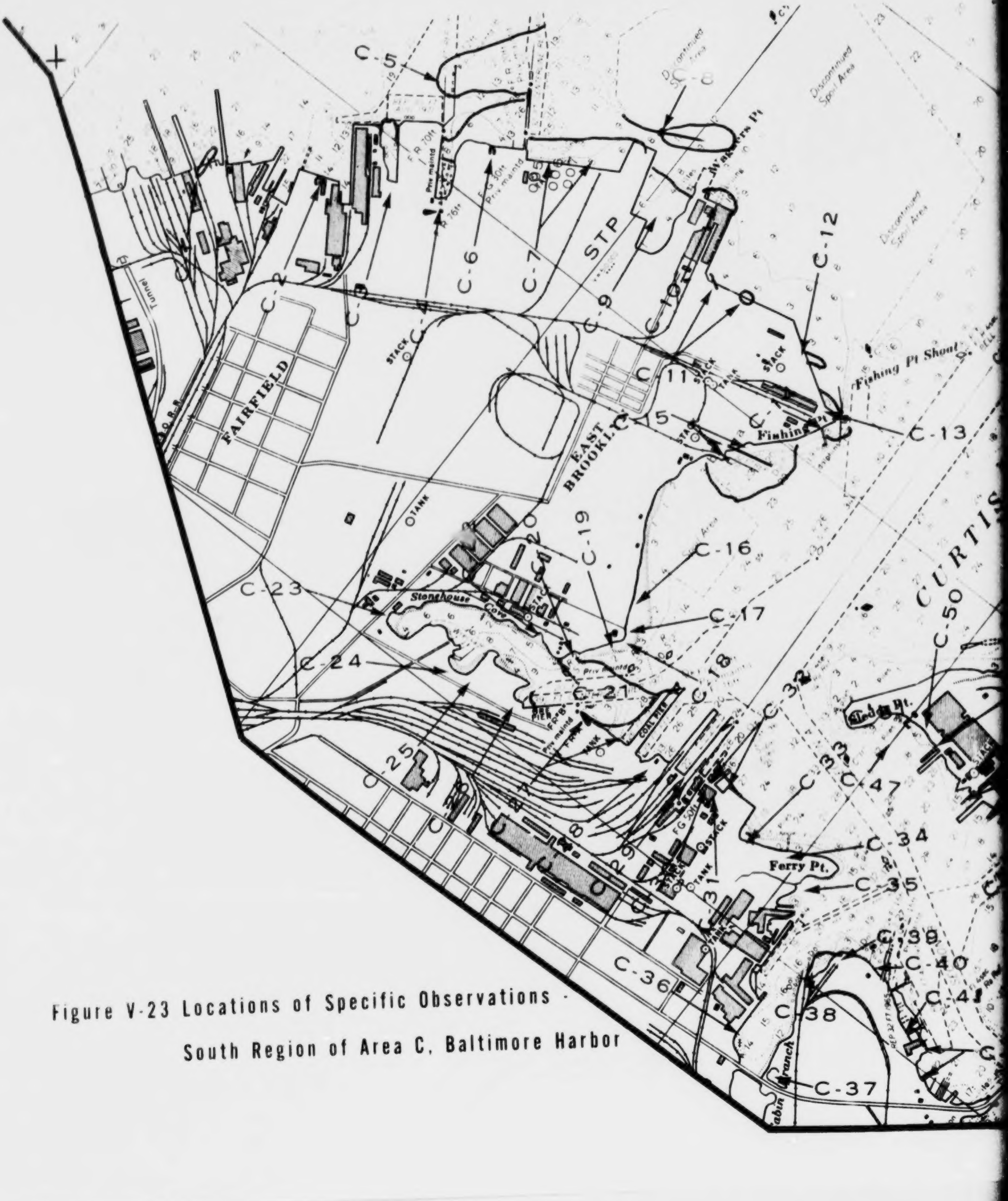
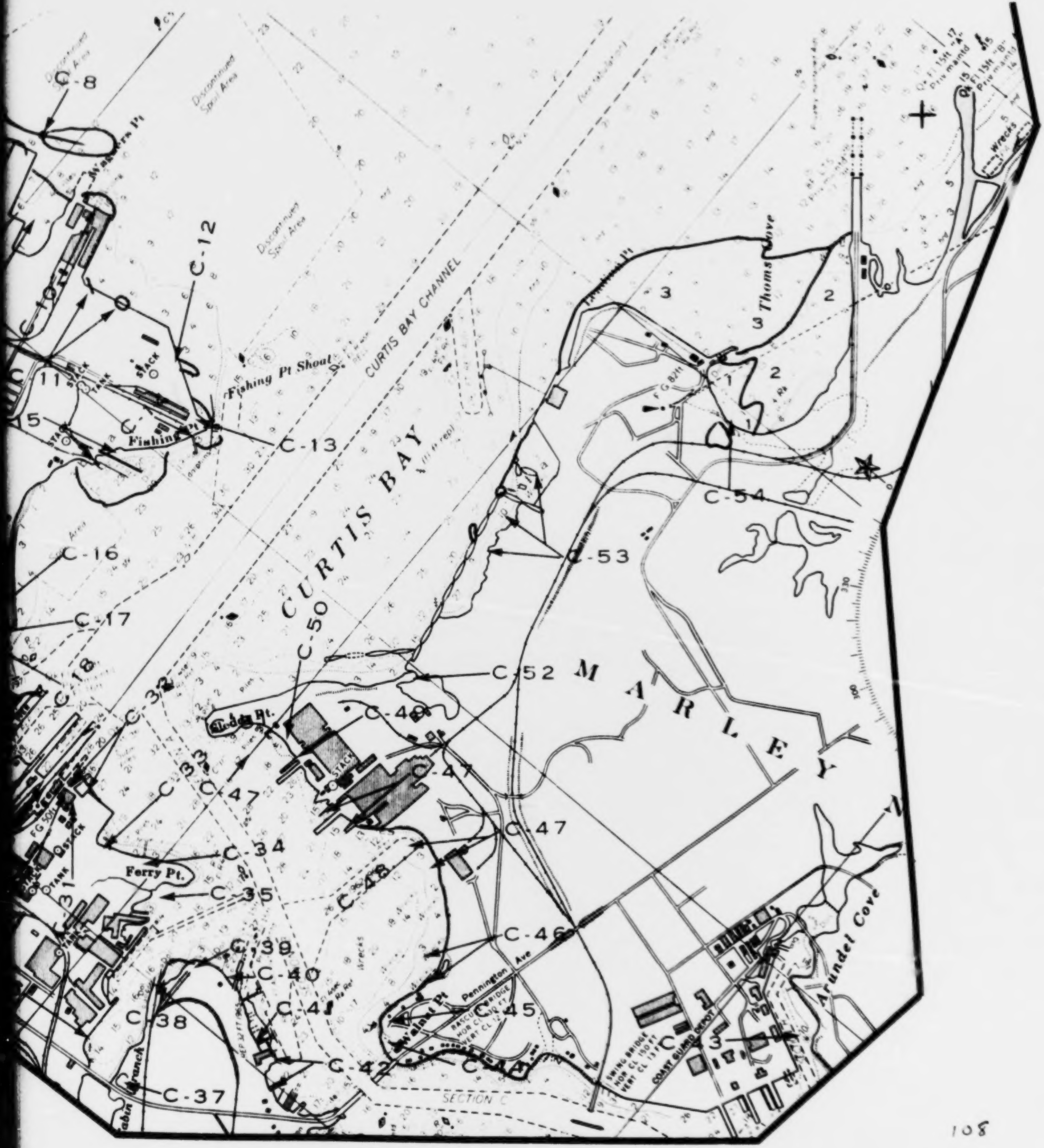

C-5
C-8
Discontinued Spoil Area
Discontinued Spoil Area
Discontinued Spoil Area
Wagners Pt
C-6
C-7
STP
C-9
C-10
C-12
C-2
C-3
C-4
Tunnel
FAIRFIELD
STACK
C-11
C-14
C-15
C-13
Fishing Pt Shoal
Fishing Pt.
EAST BROOKLYN
TANK
C-20
C-22
C-19
C-16
C-23
Stonehouse Cove
C-17
C-24
C-21
C-18
COAL PIER
C-32
CURTIS
C-50
C-25
C-26
C-27
C-28
C-29
C-30
C-31
C-33
C-47
C-34
Ferry Pt.
C-35
C-36
C-38
C-39
C-40
C-41
C-37

Figure V-23 Locations of Specific Observations - South Region of Area C, Baltimore Harbor


C-8
Discontinued Spoil Area
C-12
C-10
C-11
C-13
Fishing Pt Shoal
Fishing Pt
STACK
TANK
CURTIS BAY CHANNEL
CURTIS BAY
C-16
C-17
C-18
C-32
C-33
C-34
C-35
Ferry Pt.
C-37
C-38
C-39
C-40
C-41
C-42
C-44
C-45
C-46
C-47
C-48
C-49
C-50
C-52
C-53
C-54
Sledds Pt.
Walnut Pt
Pennington Ave
Thoms Cove
Arundel Cove
MARLEY
SWING BRIDGE
COAST GUARD DEPOT
Wrecks
SECTION C

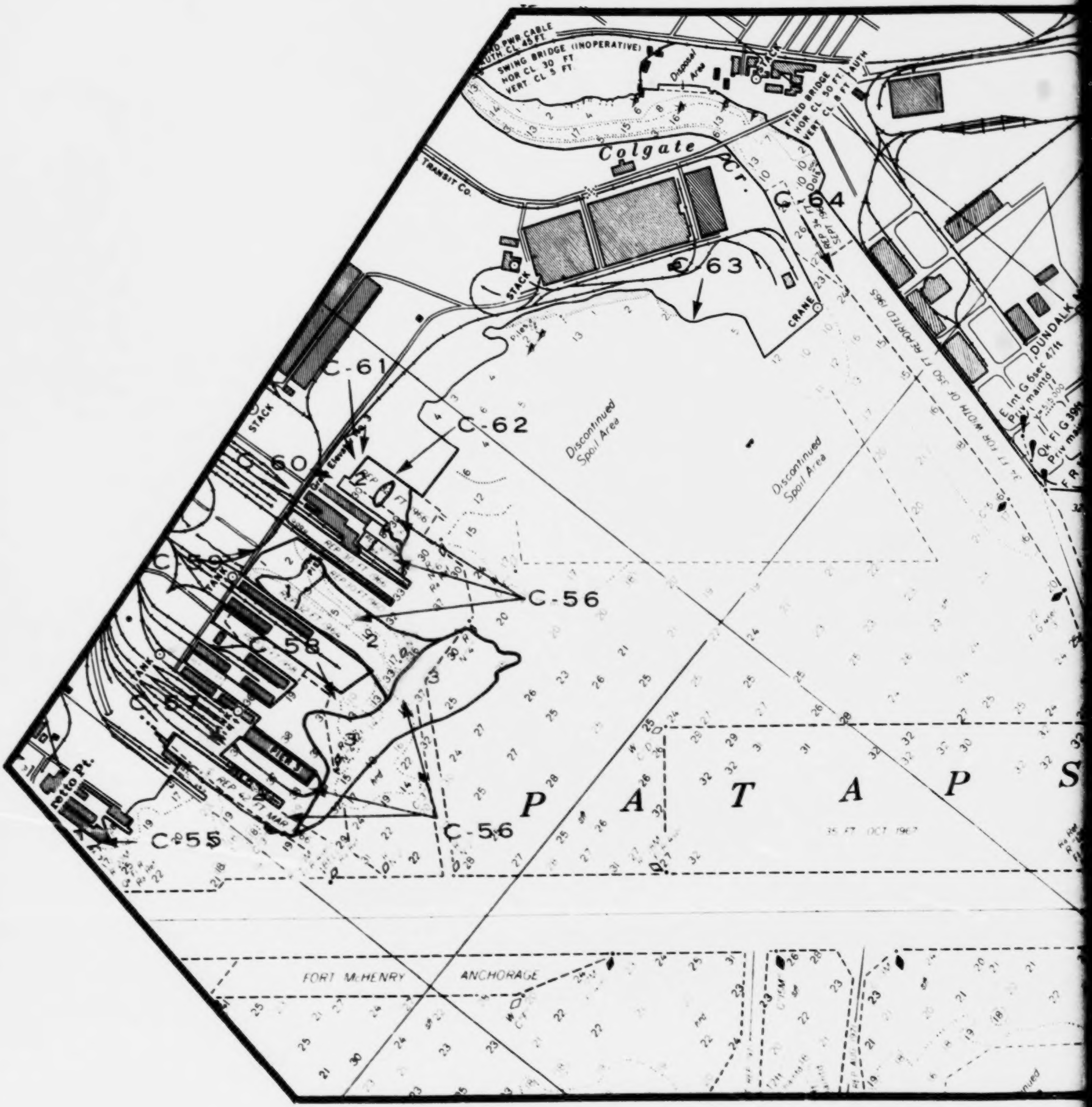
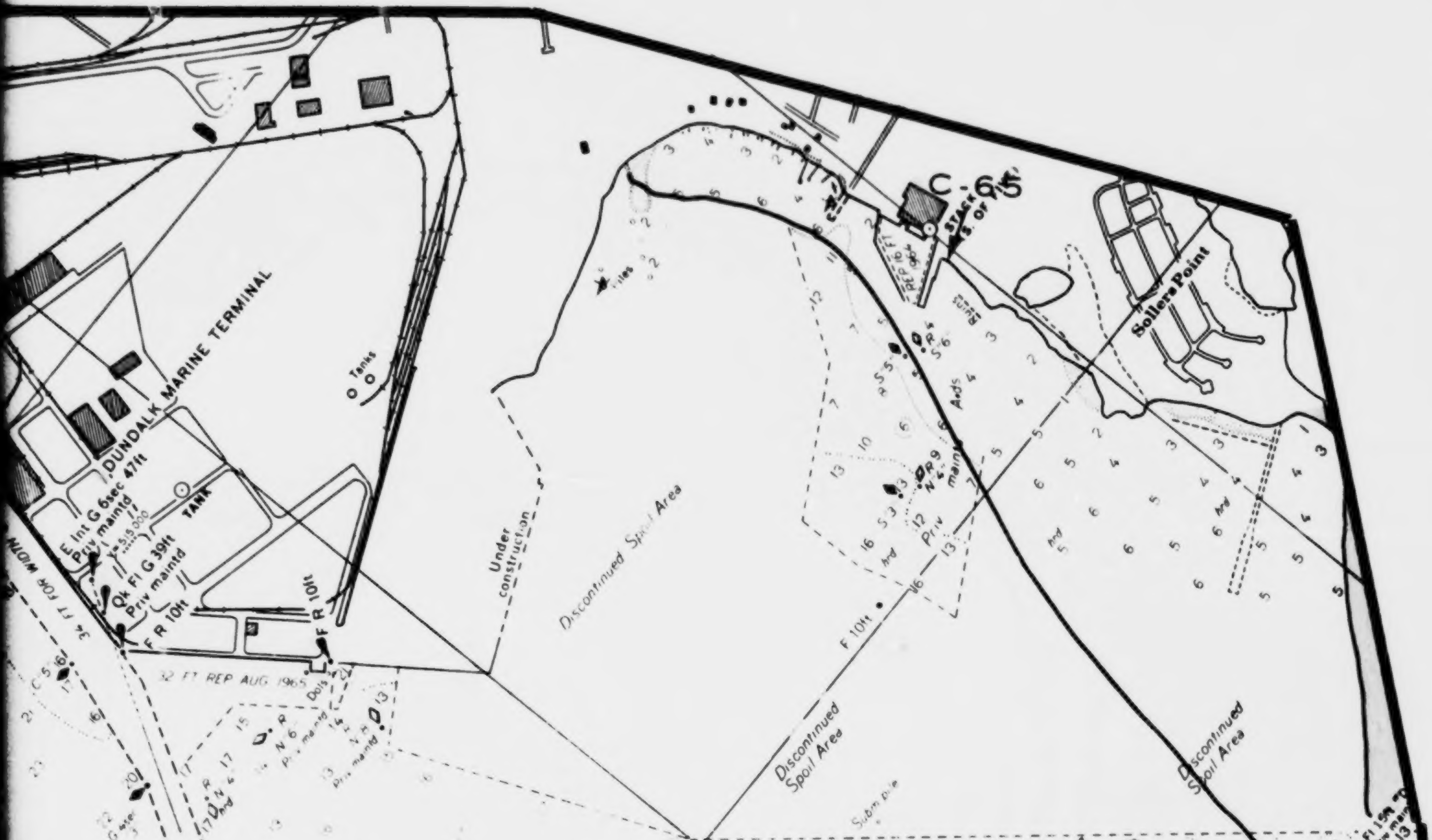

SWING BRIDGE (INOPERATIVE)
HOR CL 30 FT
VERT CL 5 FT
Disposal Area
FIXED BRIDGE
HOR CL 50 FT
VERT CL 8 FT
Colgate Cr.
TRANSIT Co.
C-64
C-63
STACK
CRANE
DUNDALK
C-61
C-62
C-60
Discontinued Spoil Area
Discontinued Spoil Area
C-56
C-58
C-56
C-55
otto Pt.
P A T A P S
35 FT OCT 1967
FORT McHENRY
ANCHORAGE

Figure V-32 Locations of Specific Observations


C-65
STACK
Sollers Point
DUNDALK MARINE TERMINAL
Tanks
TANK
E Int G 6sec 47ft Priv maintd
Qk Fl G 39ft Priv maintd
F R 10ft
F R 10ft
32 FT REP AUG 1965
Under construction
Discontinued Spoil Area
Discontinued Spoil Area
Discontinued Spoil Area
F 10ft
Priv maintd
Ads
Subm pile
34 FT FOR WIDTH OF 250 FT REPORTED 1965
34 FT FOR WIDTH
28 FT OCT 1967
S C O R I V E R
FORT McHENRY CHANNEL

ervations - North Region of Area C, Baltimore Harbor

108(a)

OUTER HARBOR AND SPARROWS POINT (AREA D)

Outer Harbor is the segment of the Patapsco River Estuary extending from the Outer Harbor Crossing to Chesapeake Bay, a distance of about 11 km (7 mi) [Figure V-1]. Study Area D covered most of the Outer Harbor and the lower reaches of tributary tidal waters [see Figure V-38, a foldout located at the end of the Area D discussion, for more detail]. Outer Harbor averages 3 to 4 km (2 to 2.5 mi) wide with several tidal arms extending an additional several kilometers away from the Harbor. On the north, Bear Creek and Old Road Bay are sizeable embayments located west and east of Sparrows Point. To the south, Stony and Rock Creek embayments enter the Harbor.

In the main Harbor area, water depths away from navigation channels range from less than 1 m (3 ft) near shore to an average of 5 m at (16 ft) mid-river. Mid-bay depths of 3 to 4 m (10 to 13 ft) in the tidal tributaries are common. Brewerton Channel, the main navigation channel entering Inner Harbor, traverses the length of Outer Harbor and is 13 m (42 ft) deep. Three shallower dredged channels connect the Sparrows Point area to the main channel.

The western shoreline of Outer Harbor and the Sparrows Point area are highly industrialized. In contrast, the southern and northeastern shorelines support residential and recreational developments.

Although tidal currents in the area are relatively small, proximity to Chesapeake Bay coupled with the large upstream tidal prism would indicate that tidal effects would be of greater significance in the movement of effluent plumes than in other Harbor areas. Surface water movements could also be substantially affected by wind currents as a result of the large water area.

General Observations

Surface waters of the Outer Harbor displayed a general dark gray-brown color. Large amounts of brown (red) algae were present with small to moderate sized areas of high suspended solids. With the exception of specific thermal fields discussed below, the variations in temperature of the surface waters were not significant.

Specific Observations

Identifying numbers for specific observations are overprinted in red on Figure V-38, a section of U. S. Coast and Geodetic Nautical Chart 549 (Scale: 1:40,000).

D-1 (Day)--The water in this small area was dark gray-brown in color. Three barges appeared to be unloading at the time of flight. An approach to a bridge (the Outer Harbor Crossing) was under construction.

D-2 (Day)--A dark yellow-gray turbidity field was present around the tip of Hawkins Point. The source of the suspended solids was not readily determined.

D-3 (Night)--A small warm spot was recorded in the surface waters at this location [Figures V-39 and V-40]. The thermal source could not be located. There was no pronounced thermal plume associated directly with this indication.

D-4 (Night)--A small thermal discharge was located adjacent to a warm pond as shown in Figures V-39 and V-40. The Glidden Company reported a storm drain at this location.

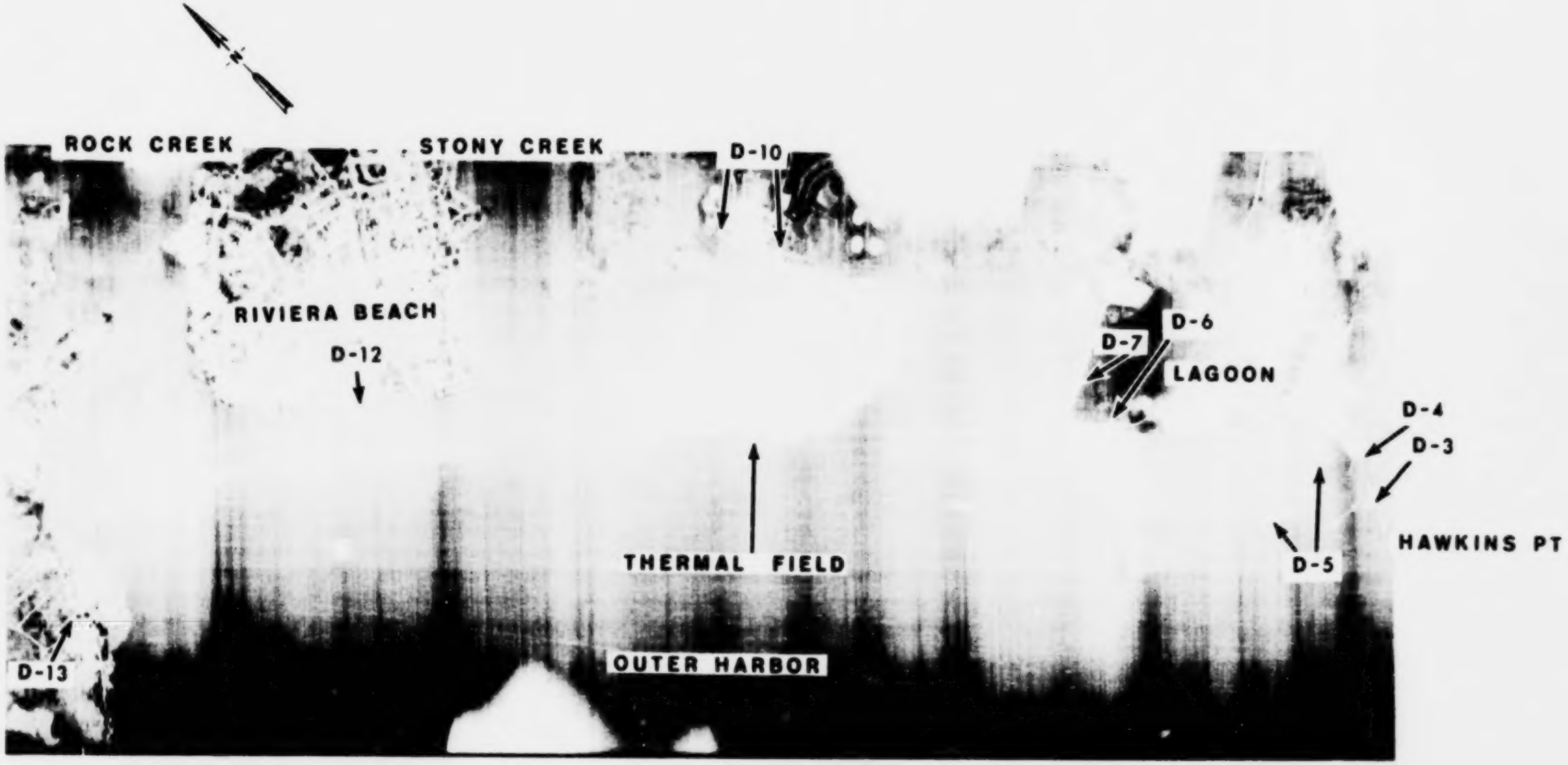

ROCK CREEK
STONY CREEK
D-10
RIVIERA BEACH
D-12
D-6
D-7
LAGOON
D-4
D-3
HAWKINS PT
D-5
THERMAL FIELD
D-13
OUTER HARBOR
N

Figure V-39 Thermal Map (Night - 2100 Hours) - West Shore , Outer Harbor

D-5 (Night)--Two submerged thermal discharges were located at the points shown. Figure V-41 is a thermal map of this area recorded at about 2030 hours (EDT), 9 May 1973, the first of a series of three thermal maps. A warm line connecting the two discharges occurred about 1.5 hours after low-low tide. The warm indications shown in Figure V-39 were recorded about 30 minutes later (2100 hours EDT). The warm line had virtually disappeared. Finally, this area was also imaged at about 2120 hours EDT [Figure V-40]. The thermal field in this general area had greatly increased in size during the 50-minute time period. The tide was in a flood phase as indicated by the line of demarcation in surface water temperatures shown in the lower middle section of Figure V-38. The Glidden Company reported these outfalls discharge mixed process wastewaters with a combined flow rate of 119,000 m^3/day (31.4 mgd) and a temperature of 24°C (76°F).

D-6 (Night)--Warm water from a lagoon located within the Kennecott Refining Corporation facility was being discharged to Outer Harbor at this particular shore position. The lagoon discharge and resultant thermal field are shown in Figures V-39, V-40 and V-41. Figure V-40 shows a cool field adjacent to the discharge occurring during the flood tide phase. An isarthermal sketch of the resultant areas of constant temperature with No. 1 being the warmest. The realtive temperature difference between Area 1 and Area 5 was estimated to have been 4 to 6°C (7 to 10°F). This isartherm was derived from thermal imagery recorded about 2100 hours EDT. The source of the warm water in the lagoon was Kennecott process and cooling water with a reported flow rate of 550 m^3/day (0.145 mgd) and a summer time temperature of 24°C (75°F).

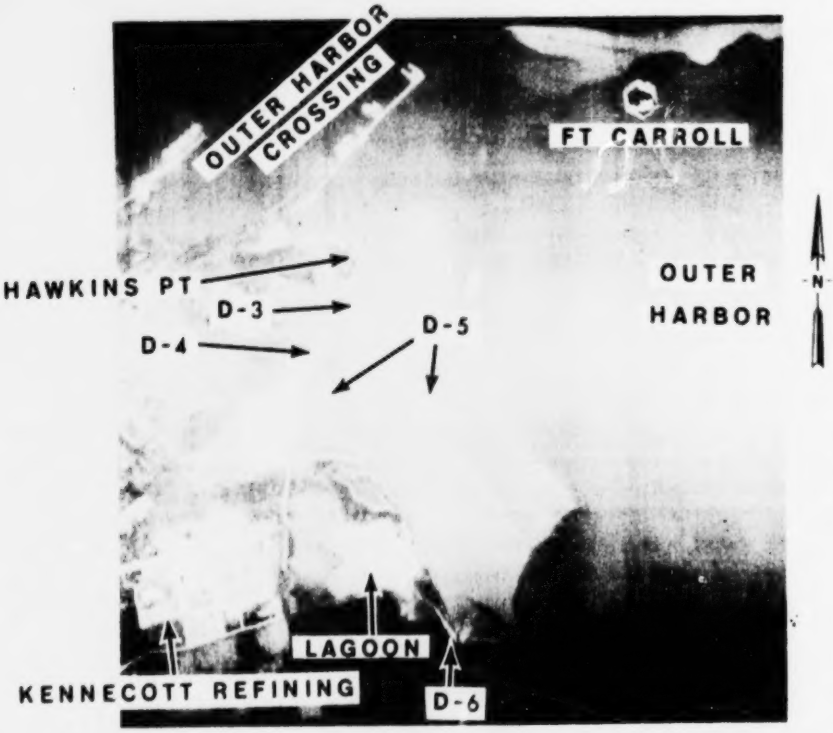

OUTER HARBOR
CROSSING
FT CARROLL
HAWKINS PT
D-3
D-4
D-5
OUTER
HARBOR
N
LAGOON
KENNECOTT REFINING
D-6

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Figure V-40 Thermal Map (Night - 2120 Hours) - Hawkins Point Area

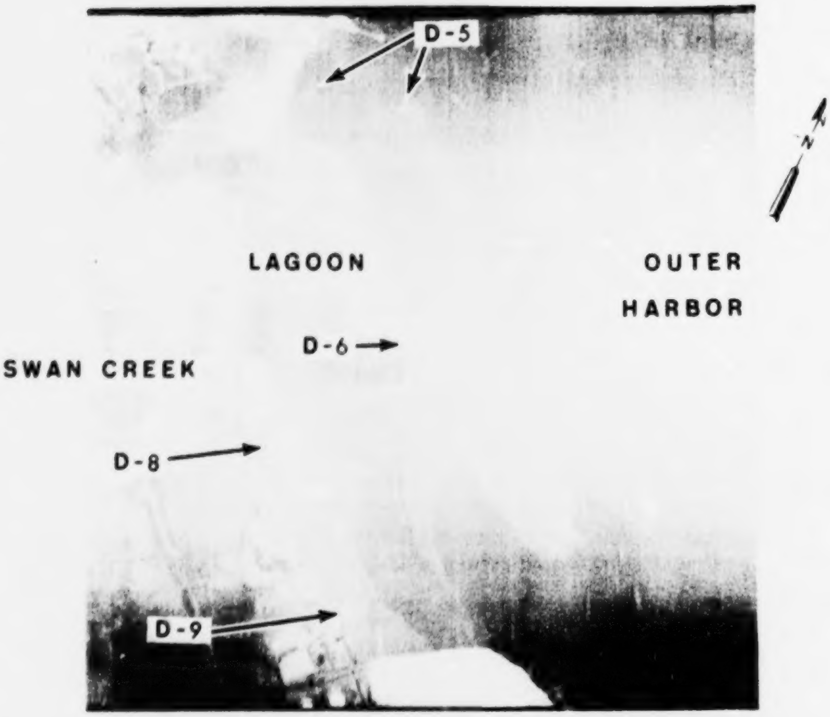
D-5
N
LAGOON
OUTER
HARBOR
D-6
SWAN CREEK
D-8
D-9

Figure V-41 Thermal Map (Night - 2030 Hours) - West Shore , Outer Harbor

D-7 (Night)--Some of the warm water in the lagoon discussed in D-6, was being discharged into Outer Harbor at this shore position [Figure V-39]. In the Kennecott permit application, this shore position was labeled "dyke outfall."

D-8 (Night)--A moderate sized lagoon was discharging warm water. The surface temperature of the lagoon was about 4 to 6°C (7 to 11°F) warmer than the Harbor water. The source of the warm water appeared to be a second (larger) pond along Swan Creek, immediately west of the first pond, and partially fed by water originating from within the Kennecott Refining Corporation facility as shown in Figures V-41 and V-43. It is noteworthy to mention that the temperature of the water of these two lagoons was nearly equal to that of the river water during the day mission as shown in Figure V-44. The thermal plume is shown in the isarthermal sketch [Figure V-42].

D-9 (Night)--A small thermal discharge was recorded at this position along shore. The resultant thermal field was small in area as shown in Figures V-41 and V-43. There was a pond or lagoon containing water 4 to 6°C (7 to 11°F) warmer than the Harbor waters, located adjacent to a small tank farm [Figure V-43], that may have been the source of warm water.

D-10 (Night)--The thermal discharges from the H. A. Wagner Generating Station were creating a large thermal field as shown in Figure V-39. The field was 4.8 km (3 mi) in length and extended 960 m (2,800 ft) into the Patapsco River from the discharges. The relative isarthermal sketch of this field is shown in Figure V-42. The surface temperature of the area labeled No. 1 was estimated to be 7 to 9°C

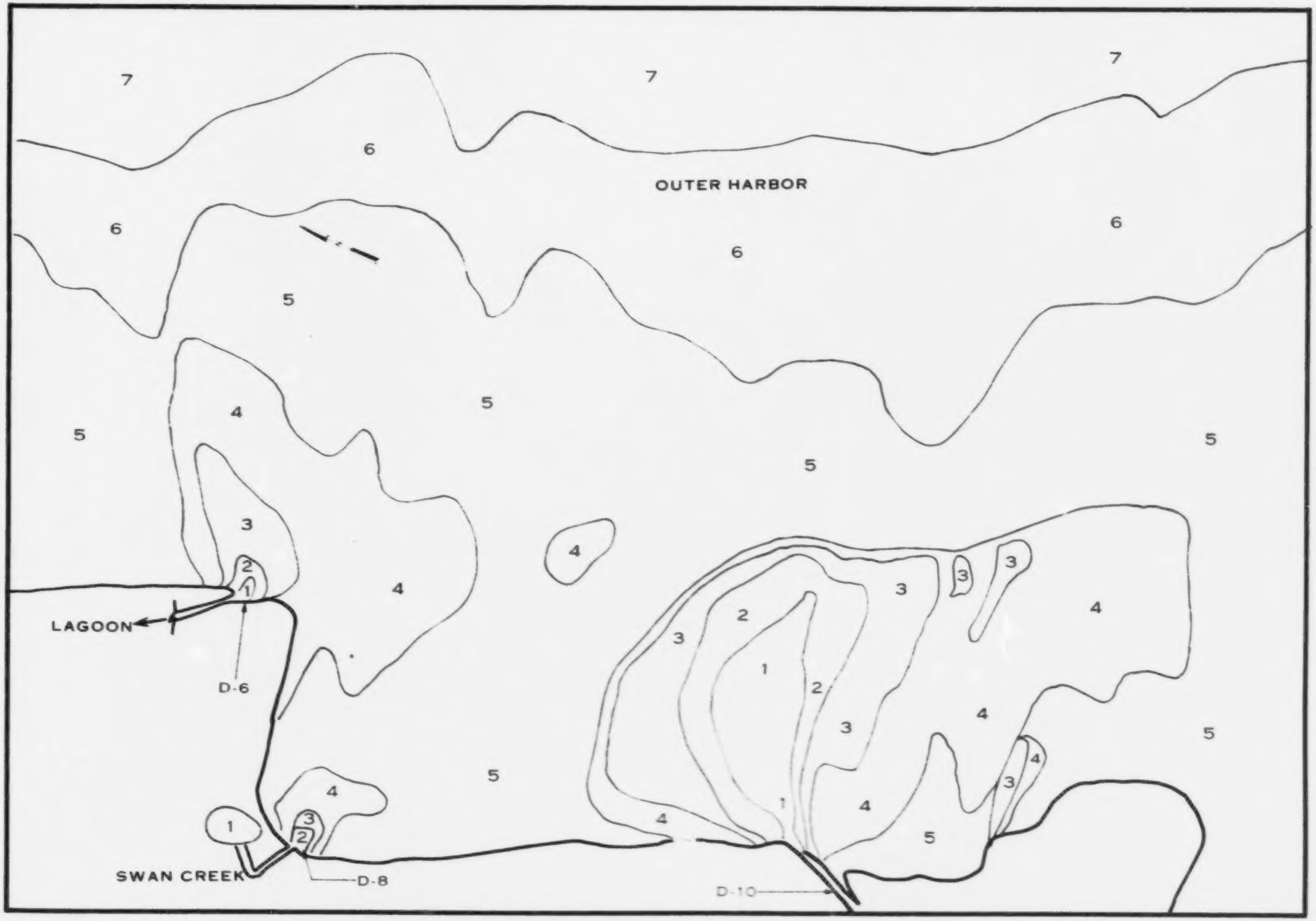
OUTER HARBOR
LAGOON
SWAN CREEK
D-6
D-8
D-10
7
6
5
4
3
2
1

Figure V-42 Isarthermal Map - Western Shore, Outer Harbor

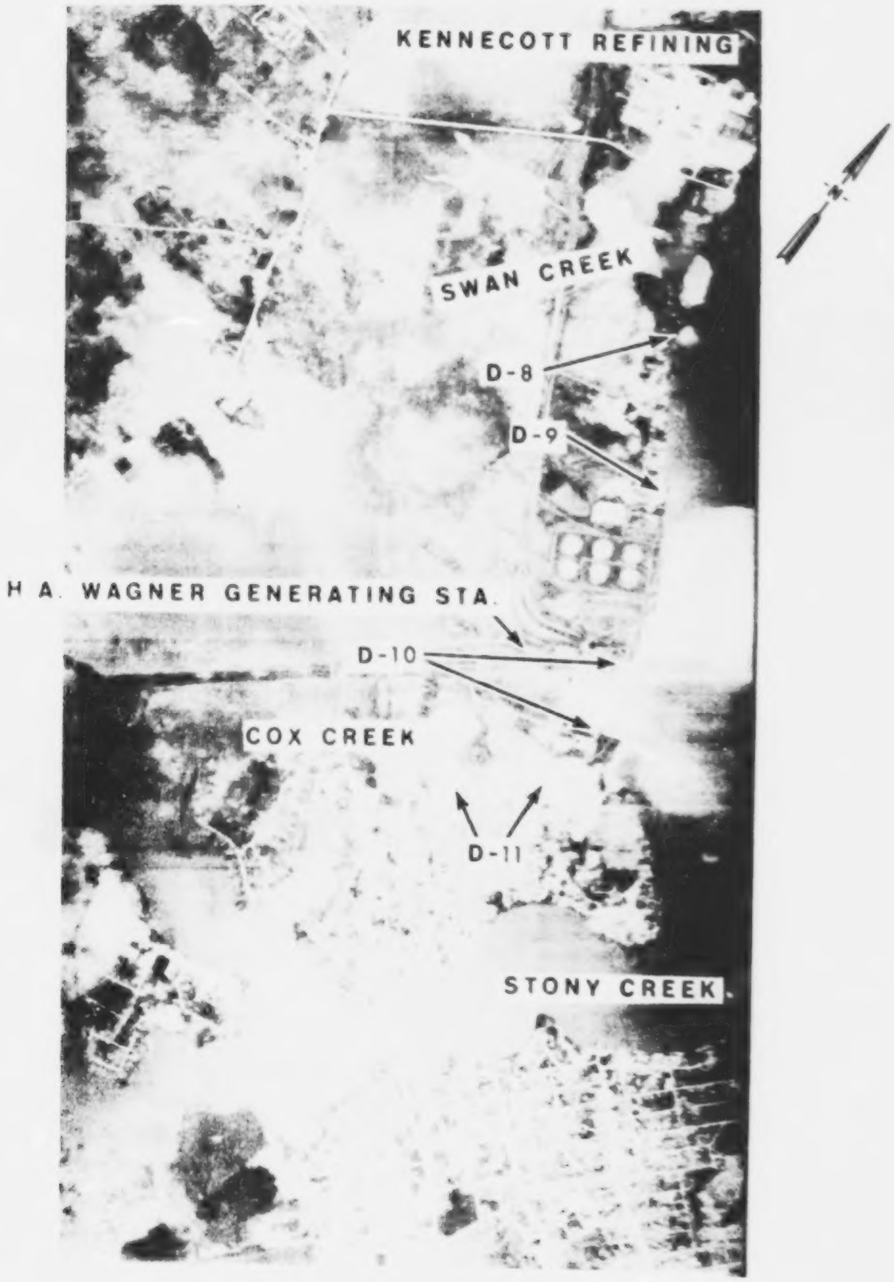
KENNECOTT REFINING
SWAN CREEK
D-8
D-9
H. A. WAGNER GENERATING STA.
D-10
COX CREEK
D-11
STONY CREEK

Figure V-43 Thermal Map (Night - 2120 Hours) - Stony Creek Area

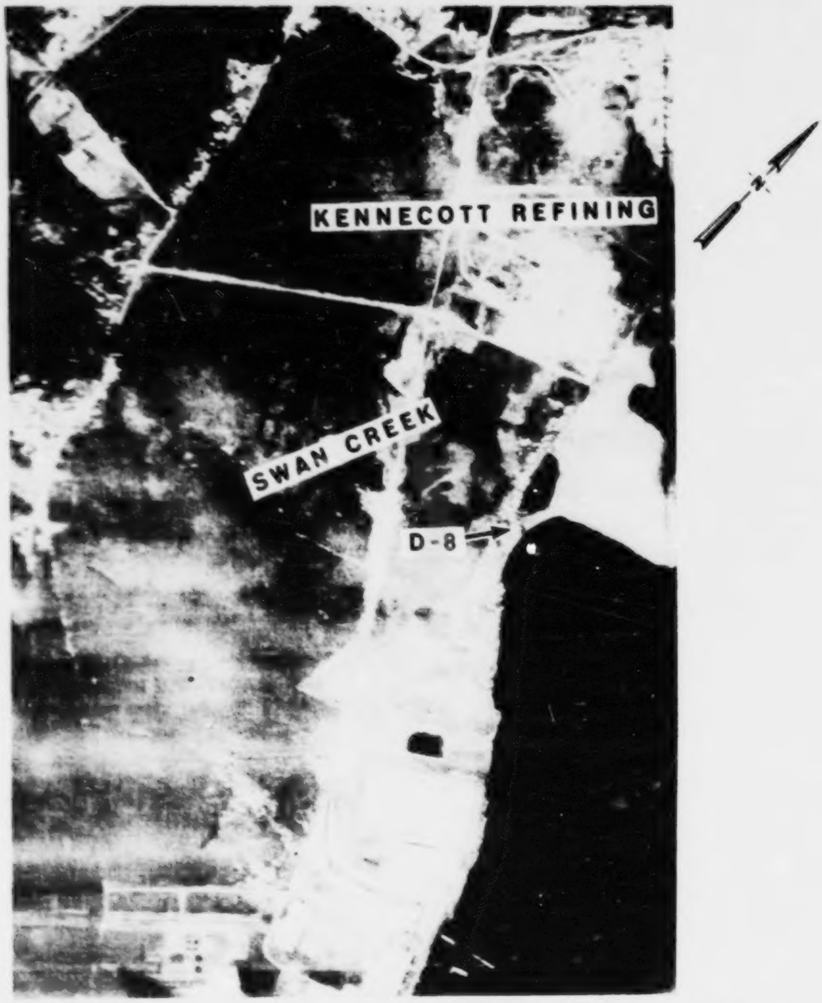
KENNECOTT REFINING
SWAN CREEK
D-8
N

Figure V-44 Thermal Map (Day) - West Shore, Outer Harbor

(13 to 16°F) warmer than the surface temperature of the river waters. The largest thermal field [Figure V-39] was produced by the discharge from Outfall 001 with a reported flow rate of 1,770,000 m^3/day (467 mgd) and a summertime temperature of 32°C (89°F). The discharge from Outfall 002 created a much smaller thermal field than Outfall 001 [Figure V-39] and appeared significantly cooler. Its reported flow rate was 1,660,000 m^3/day (438 mgd), only 6 percent smaller than the discharge from 001. It had a summertime discharge temperature of 31°C (88°F). The thermal map [Figure V-43] recorded about 20 minutes later than Figure V-39 clearly shows that the dispersion characteristics of the Outfall 002 effluent had changed significantly in the flood tide phase from that indicated in the earlier thermal map.

D-11 (Night)--The surface waters in Cox Creek were significantly warmer than the ambient waters of the Outer Harbor [Figure V-43]. There was a sharp thermal boundary across the mouth of the creek. The discharges discussed in D-10 did not significantly contribute to this condition.

D-12 (Night)--A small thermal discharge was entering the Patapsco River at this location on Riviera Beach [Figure V-39]. There was a small pond located adjacent to shore that may have been the source of the warm water.

D-13 (Night)--A thermal discharge was recorded at this shore position adjacent to two small docks. The resultant thermal field is shown in Figure V-39. The source of the warm water was not readily determined.

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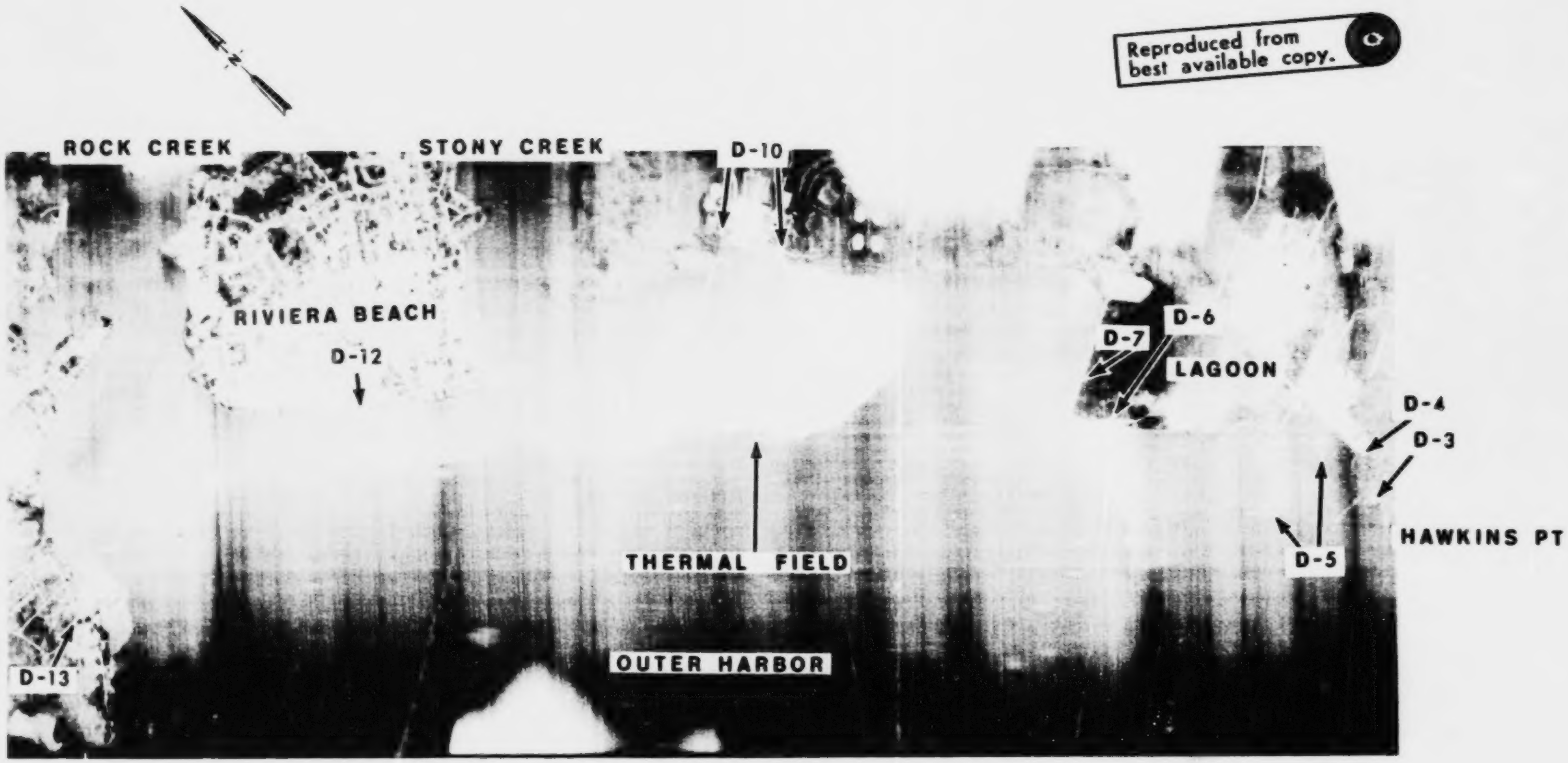

N
ROCK CREEK
STONY CREEK
D-10
RIVIERA BEACH
D-12
D-6
D-7
LAGOON
D-4
D-3
HAWKINS PT
D-5
THERMAL FIELD
OUTER HARBOR
D-13

Figure V-39 Thermal Map (Night - 2100 Hours) - West Shore , Outer Harbor

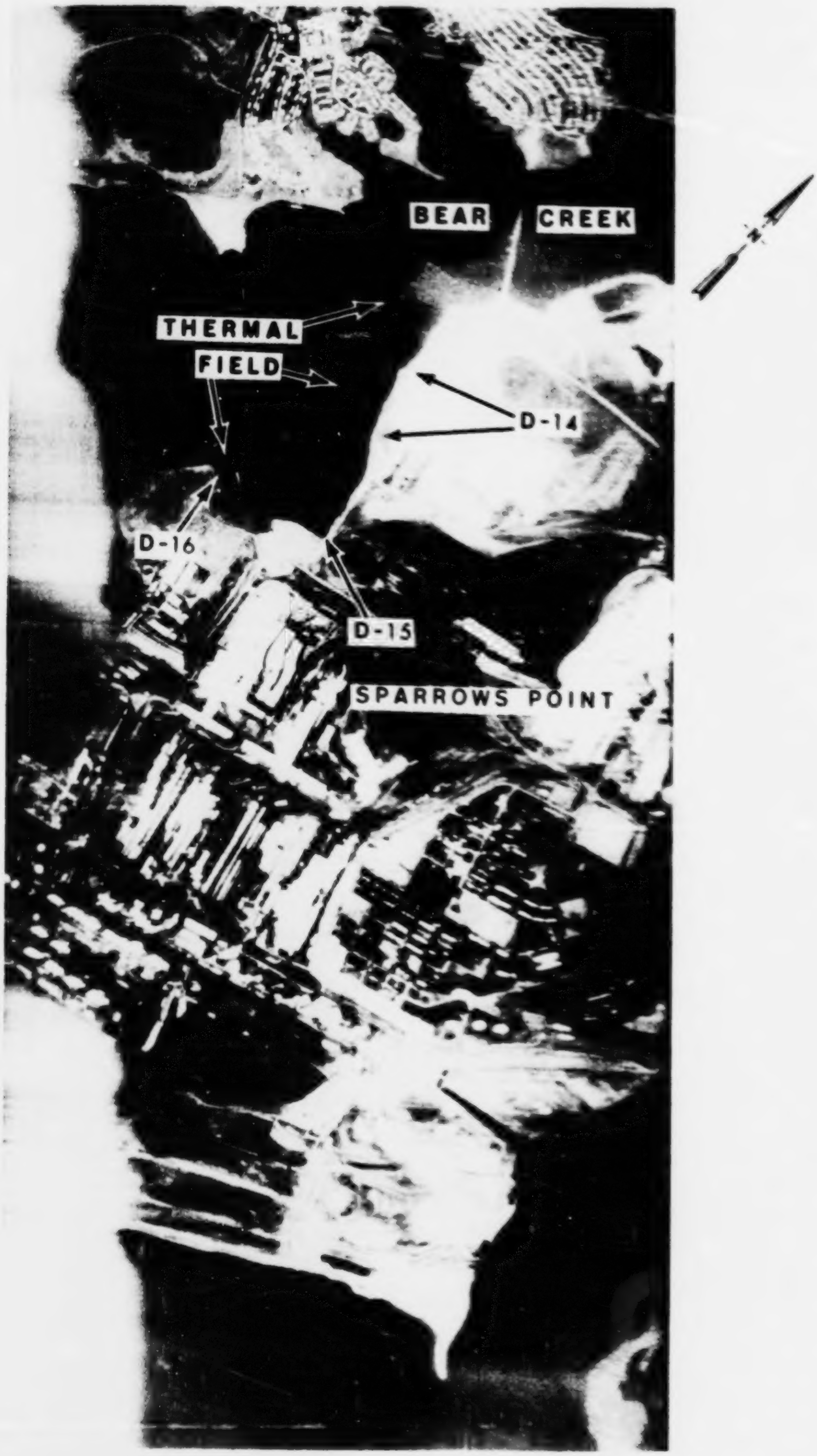

BEAR
CREEK
THERMAL
FIELD
D-14
D-16
D-15
SPARROWS POINT

Figure V-45 Thermal Map (Day) - Bear Creek, Sparrows Point

D-14 (Day)--The water in this area of Bear Creek was dark gray-brown and contained a significant amount of suspended solids. The surface waters of this area were somewhat warmer than the Creek background waters as shown in Figure V-45. This indication was in the immediate zone of influence of Outfall 015 within the Bethlehem Steel Corporation's Sparrows Point Facility as shown by arrow "a" [Figure V-38]. This discharge reportedly consists of 7,600 m^3/day (2.0 mgd) of process water and 9,800 m^3/day (2.6 mgd) of non-contact cooling water. The summertime average temperature was given as 31°C (87°F) for the combined discharge and the pH range was 4.0 to 7.6. Bethlehem's Outfalls 018 and 019 were located about 270 m (880 ft) south of Outfall 015. No flow rate information was available for these outfalls.

D-15 (Day)--Bethlehem Steel Corporation's Outfall 014 was producing a small thermal field at this shore position [Figure V-45]. The discharge reportedly consists of 303,000 m^3/day (80 mgd) of process water and 8,300 m^3/day (2.2 mgd) of non-contact cooling water with an average summertime temperature of 32°C (90°F).

D-16 (Day)--The surface waters in this immediate area were quite dark brown and an isolated thermal plume was recorded as shown in Figure V-45. This area is sketched in detail in Figure V-46. The source of the indication could not be determined.

D-17 (Day)--A thermal field was present in this area as shown in Figure V-47 and sketched in Figure V-46. The source of the warm water was not readily determined. Surface water within the thermal field was somewhat less turbid than the background water. The estimated temperature difference between the surface waters of the field and the

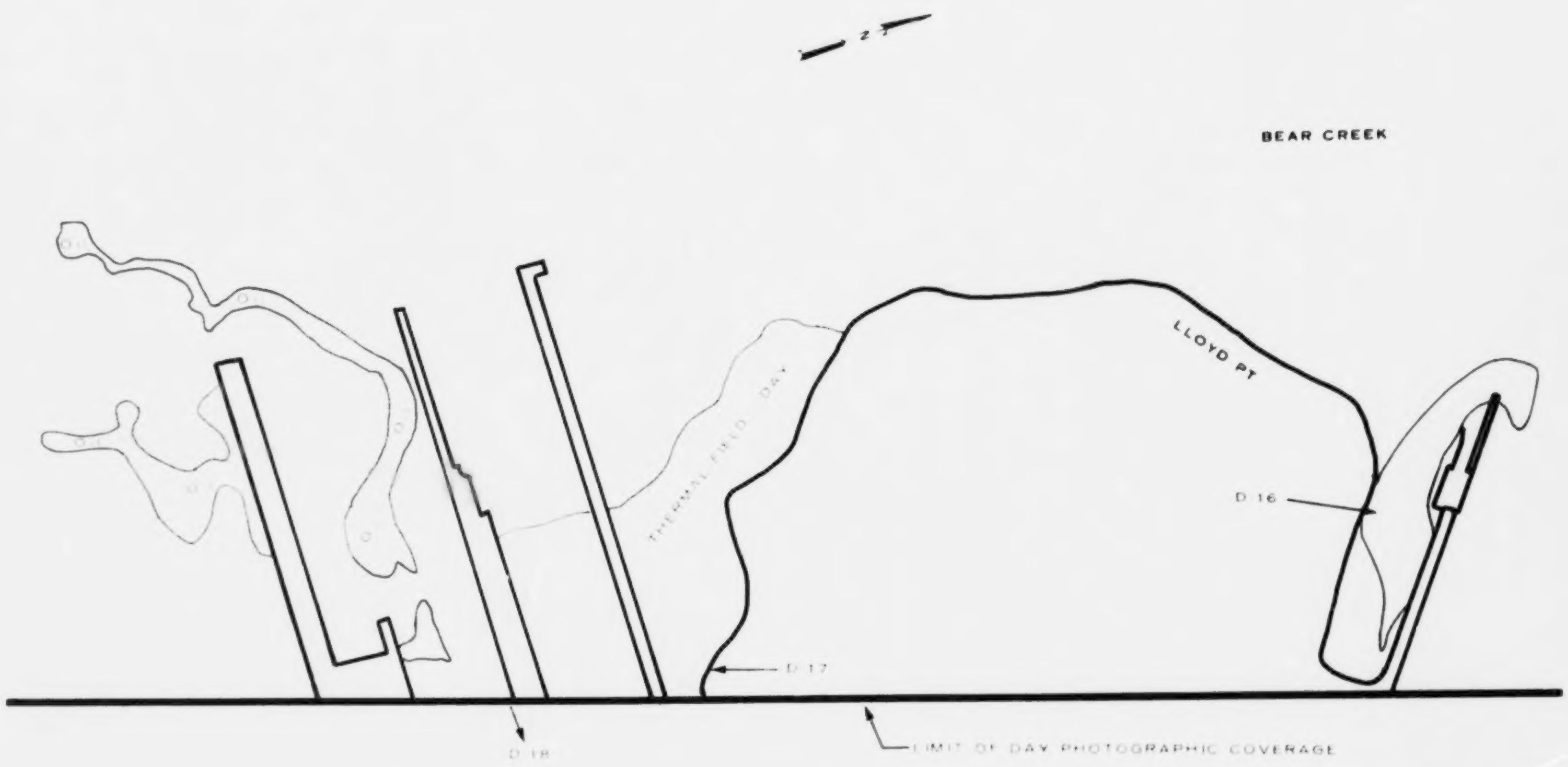

BEAR CREEK
LLOYD PT
D 16
D 17
D 18
THERMAL FIELD - DAY
LIMIT OF DAY PHOTOGRAPHIC COVERAGE

Figure V-46 Detailed Observations - Northwest Shore, Sparrows Point

Patapsco River waters was about 2 to 4°C (4 to 7°F).

D-17 (Night)--The thermal field was also present during the night flight but not as warm as the above. During this mission a warm indication was recorded on shore as shown in Figure V-48 and sketched in Figure V-46. The warm water extended from this shore position in a southerly direction toward the pier.

D-18 (Day)--A thermal field between two piers was recorded in this area along with numerous oil slicks. The field is shown in Figure V-47 as it was moving out into the Patapsco River waters. The estimated difference in temperature between the surface waters of the field and the river waters was 2 to 4°C (4 to 7°F). The oil slicks are sketched in Figure V-46. The amount of oil contained in these slicks was about 61 liters (16 gal.).

D-18 (Night)--The thermal field was also present in this dock area during the night mission. The source of the warm water was in the northeastern corner of the dock area as shown in Figure V-48. This discharge was from Bethlehem Steel Corporation's Outfall 013 with a reported flow rate of 28,400 m^3/day (7.5 mgd) of process water and 51,100 m^3/day (13.5 mgd) of non-contact cooling water with a summertime average temperature of 33°C (92°F).

D-19 (Day)--Bethlehem Steel Corporation's Outfall 012 was discharging warm water at the apex of this dock area. With the tide in an ebb phase at the time of flight, the warm water was flowing out into the Patapsco River and impinging upon a still warmer thermal field (to be discussed in D-20) as shown in Figure V-47. This discharge reportedly

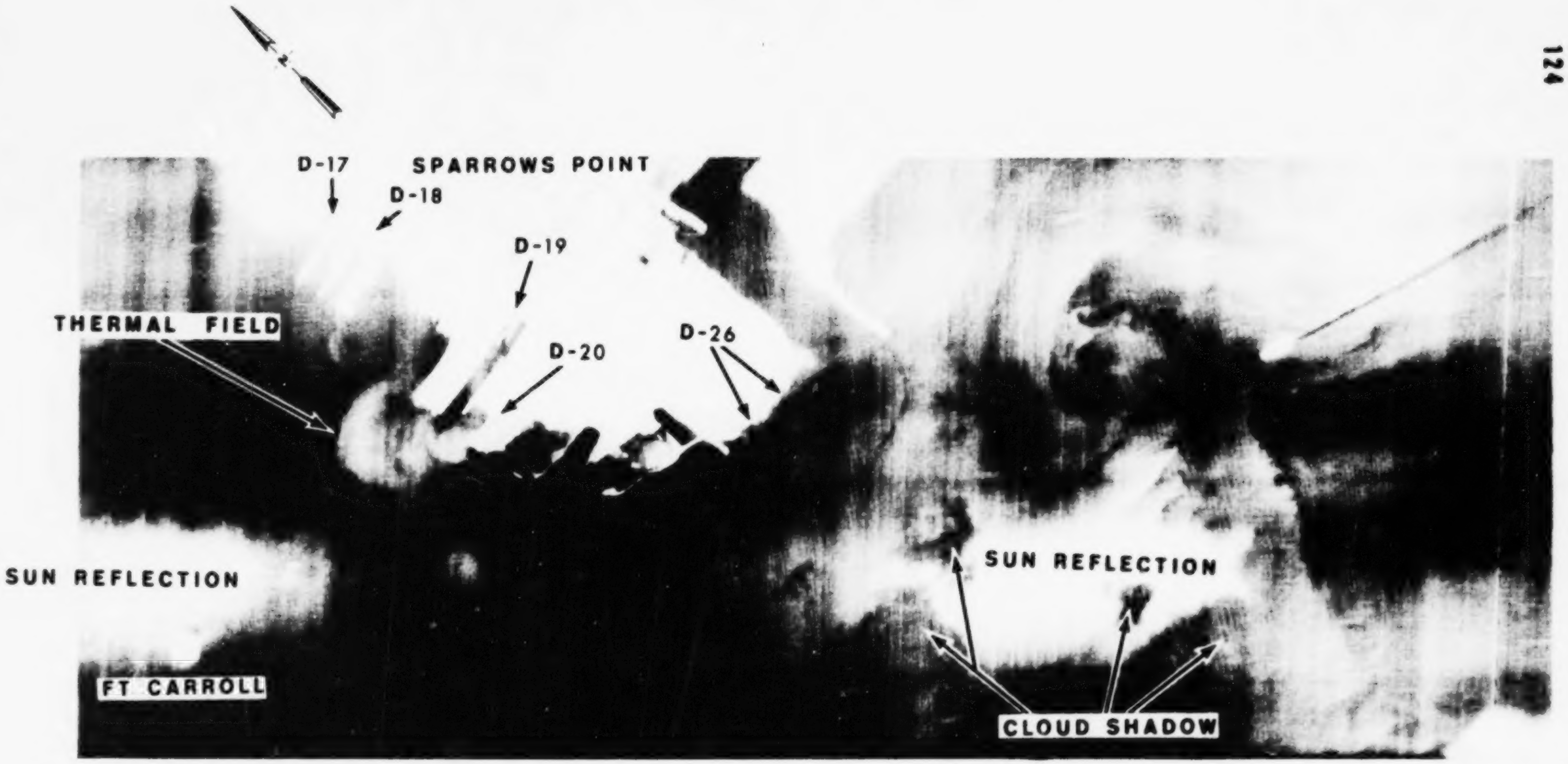
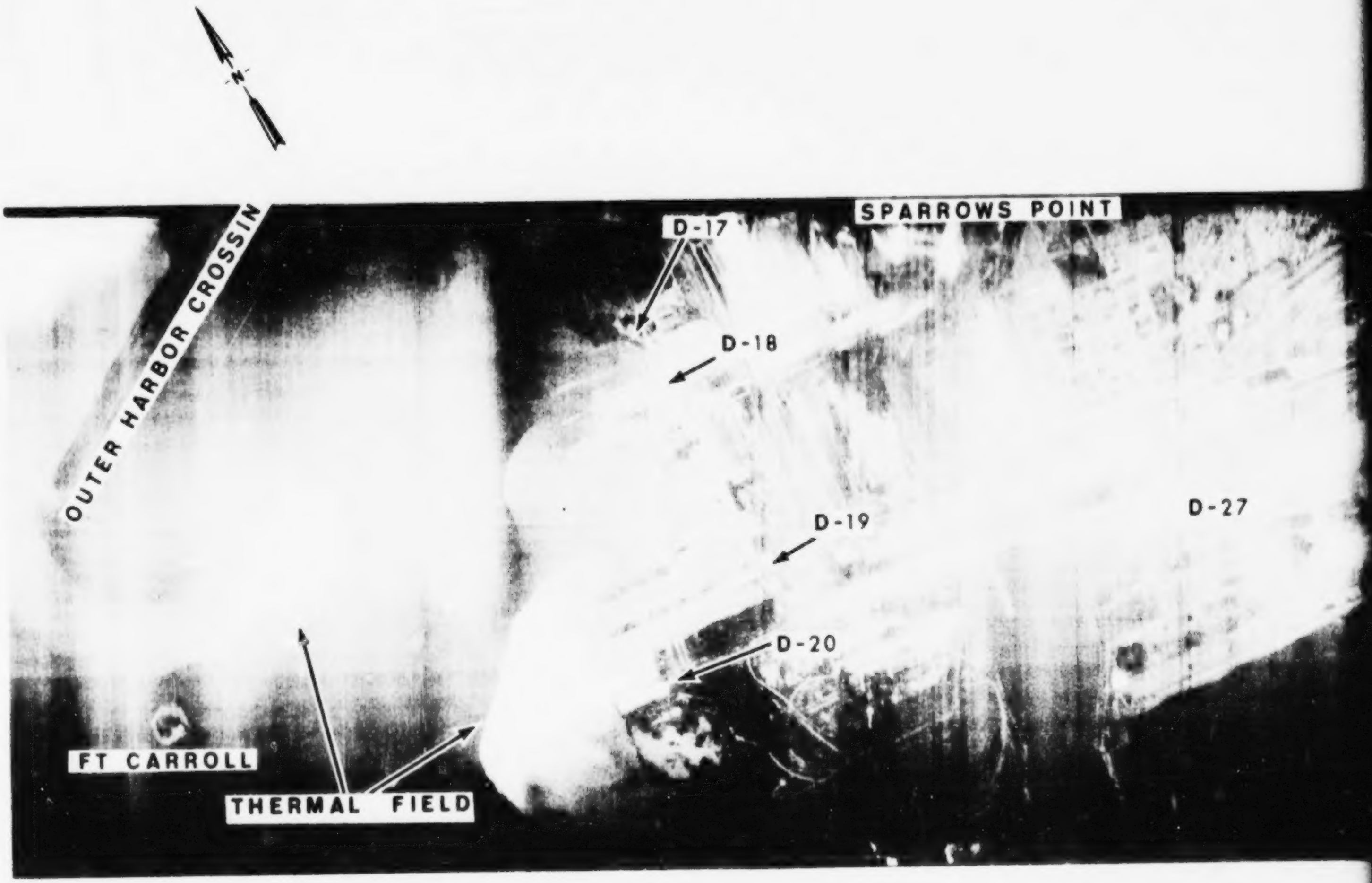

D-17
SPARROWS POINT
D-18
D-19
THERMAL FIELD
D-20
D-26
SUN REFLECTION
FT CARROLL
SUN REFLECTION
CLOUD SHADOW

Figure V-47 Thermal Map (Day) - Southwest Shore, Sparrows Point


N
OUTER HARBOR CROSSIN
SPARROWS POINT
D-17
D-18
D-19
D-20
D-27
FT CARROLL
THERMAL FIELD

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OINT
OLD ROAD BAY
D-30
D-27
SHALLOW CREEK
D-33
NORTH POINT
PATAPSCO RIVER
THERMAL FIELD

Figure V-48 Thermal Map (Night) - Sparrows Point

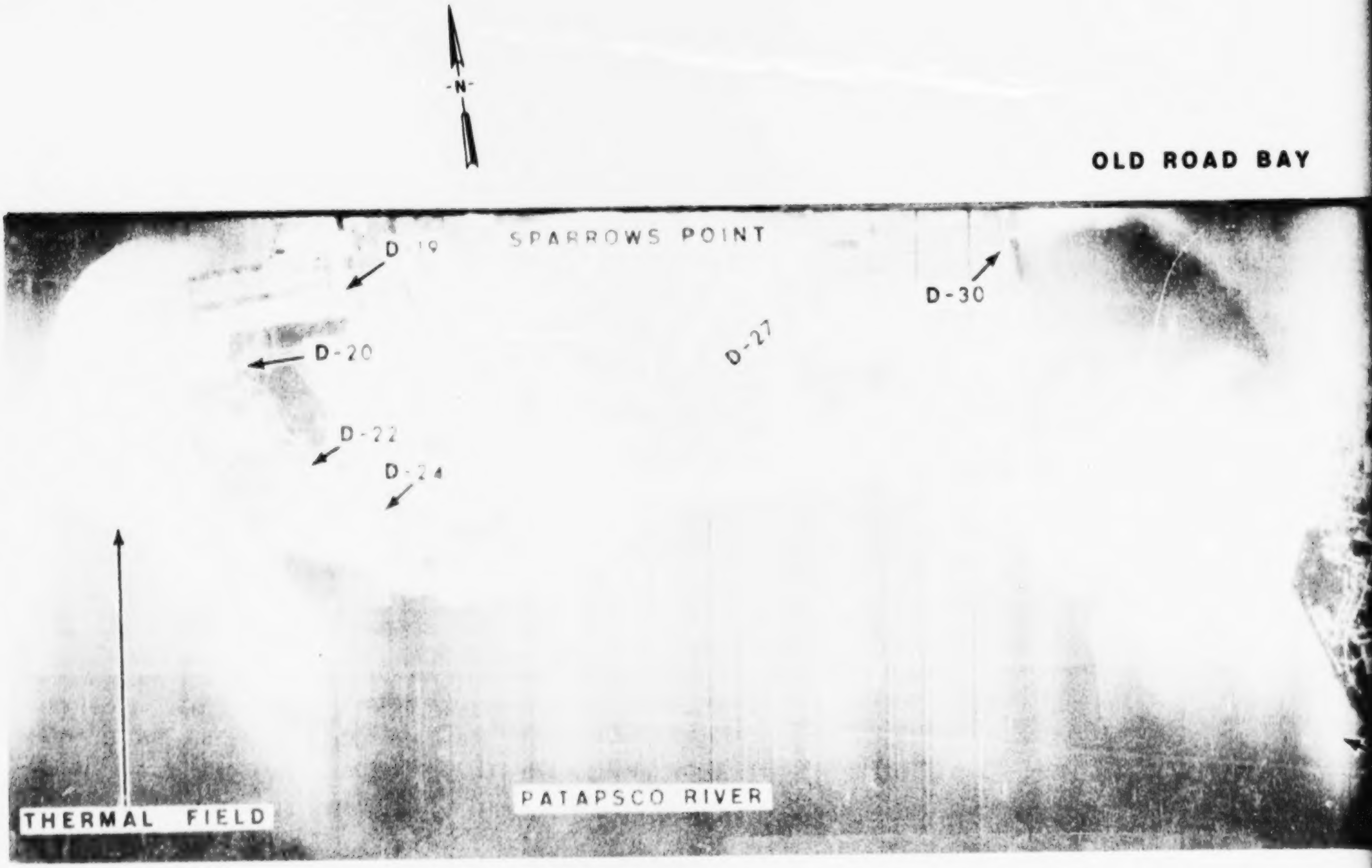
N
OLD ROAD BAY
SPARROWS POINT
D-19
D-20
D-22
D-24
D-27
D-30
THERMAL FIELD
PATAPSCO RIVER

Figure V-49 Therma

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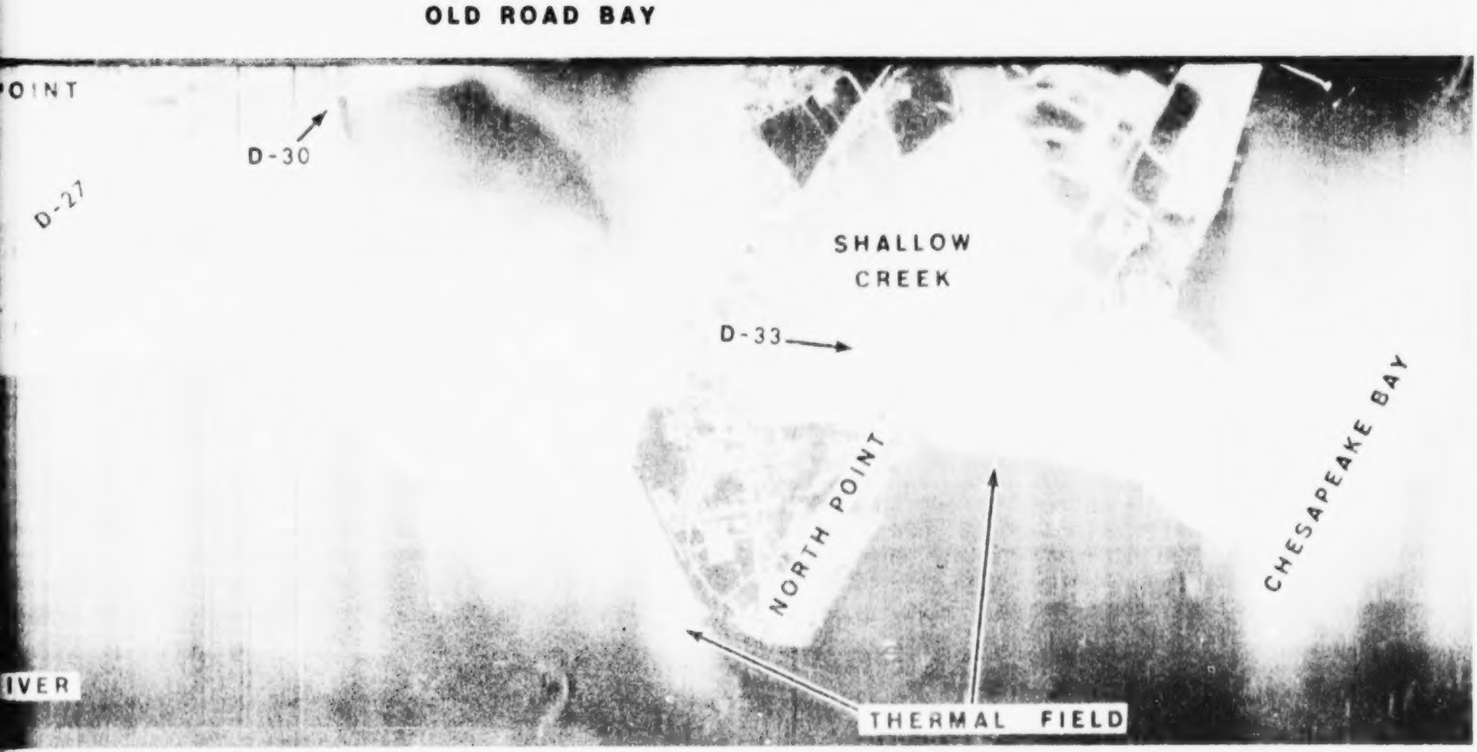

OLD ROAD BAY
OINT
D-30
D-27
SHALLOW CREEK
D-33
NORTH POINT
CHESAPEAKE BAY
IVER
THERMAL FIELD

Figure V-49 Thermal Map (Night) - North Shore, Outer Harbor

consisted of 466,000 m^3/day (123 mgd) of process and non-contact cooling water with a summertime temperature of 33°C (92°F).

D-19 (Night)--The thermal field resulting from Outfall 012 was also moving out into the warmer D-20 thermal field as shown in Figure V-48. This was occurring during a flood tide condition from low-low tide to low-high tide. The surface temperature of this field was estimated to be 3°C (5°F) cooler than that of D-20 and 2 to 3°C (4 to 5°F) warmer than the background Patapsco River waters. The discharge and thermal field are also shown in Figure V-49 recorded about 21 minutes later than Figure V-48.

D-20 (Day)--Bethlehem Steel Corporation's Outfalls 009, 010 and 011 were discharging from this shore position as shown in Figure V-50. Oil in the form of surface oil slicks was moving from the rectangular discharge basin out into the Patapsco River. The amount of oil in the slicks was calculated to be 57 liters (15 gal.). There was also a large thermal field present which resulted from the combined discharge as shown in Figure V-47. This combined discharge reportedly consisted of 327,000 m^3/day (86.4 mgd) of process and non-contact cooling water with an average summertime temperature of 39°C (102°F).

D-20 (Night)--The combined discharge of Outfalls 009, 010 and 011 created a more prominent thermal field than recorded during the day flight [Figure V-48]. With the tide progressing from a slack condition into the flood phase, the thermal field possessed sharper thermal boundaries in the Patapsco River than during the day flight. The field was density sliced and subsequently synthesized into the isarthermal map

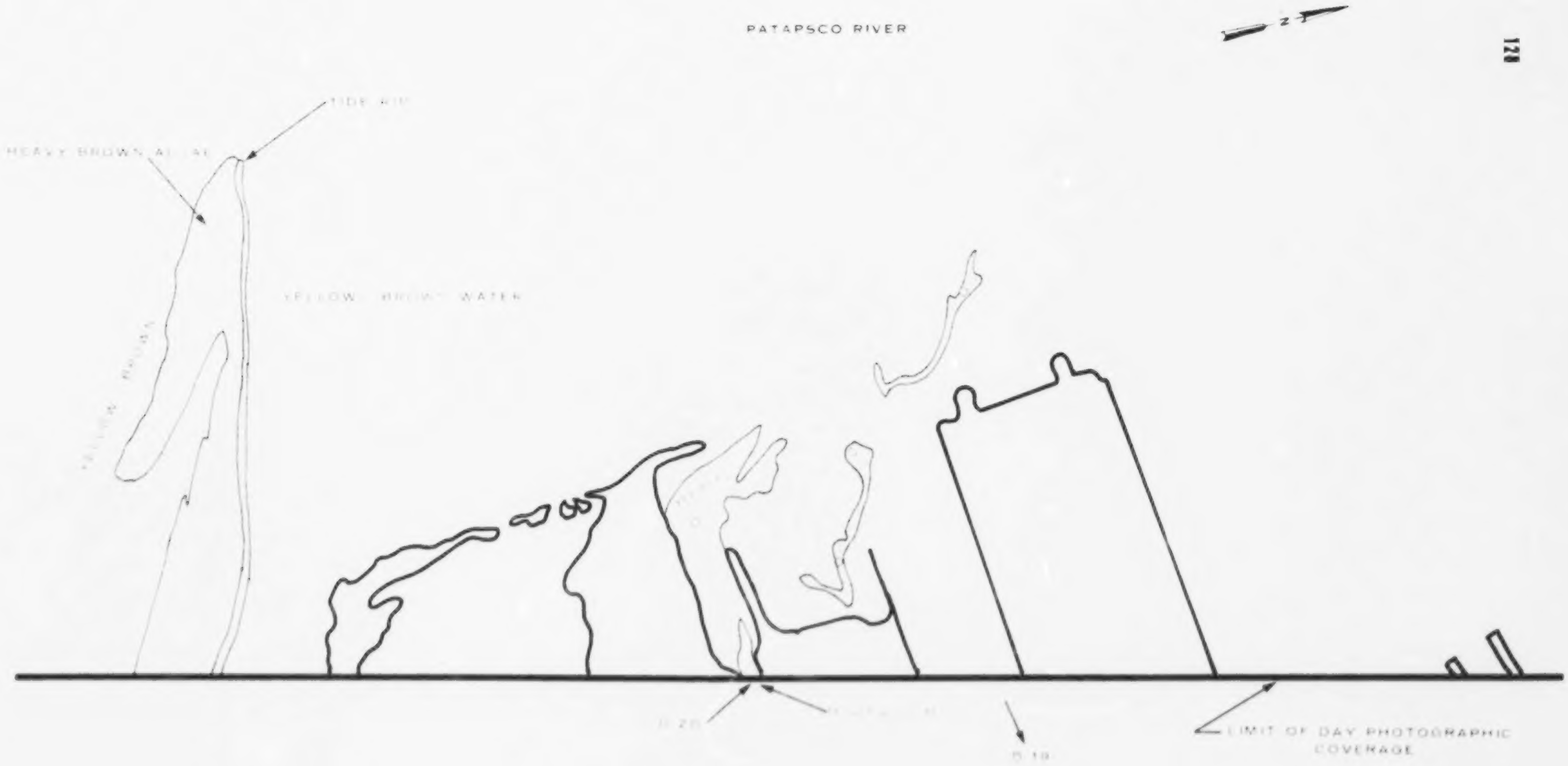

PATAPSCO RIVER
N
TIDE RIP
HEAVY BROWN ALGAE
YELLOW BROWN WATER
YELLOW BROWN
D 20
D 19
LIMIT OF DAY PHOTOGRAPHIC COVERAGE

Figure V-50 Detailed Observations - West Shore, Sparrows Point

Figure V-51. Two separate areas in this map are labeled No. 1, the warmest indication. The estimated surface temperature difference between the No. 1 area and the background river waters was 6 to 8°C (11 to 14°F). Approximately twelve minutes later this thermal field was again imaged as shown in Figure V-49. The field covered a much larger surface area at the later time, extending further out into the river and southward even though a flood tide condition was present. The two black lines across the outer boundaries of the field were caused by Harbor boat traffic, indicating that the water below the surface was significantly cooler than at the surface by about 2 to 4°C (4 to 7°F). An isarthermal map of the field in Figure V-49 is provided as Figure V-52. A detailed study of the size and location of each relative isartherm in Figures V-51 and V-52 would provide the evolvement data for the field during this short time interval.

D-21 (Day)--A gray-colored runoff wastewater was entering the mud flat from the paths labeled "a" through "e" in Figure V-53. The turbid water then entered the Patapsco River along the paths indicated by arrows "f" and "g." The effluent caused a yellow-gray turbid condition in the river as depicted in the figure.

D-22 (Day)--A small volume of wastewater was flowing along the ditch labeled "h" in Figure V-53. The effluent subsequently entered the geometrically shaped slip. Any resultant discoloration in the receiving water was not recorded because of large concentrations of brown algae as indicated in Figure V-53 by the areas labeled Nos. 1, 2 and 3 with 1 as the greatest concentration. Bethlehem Steel Corporation's Outfall

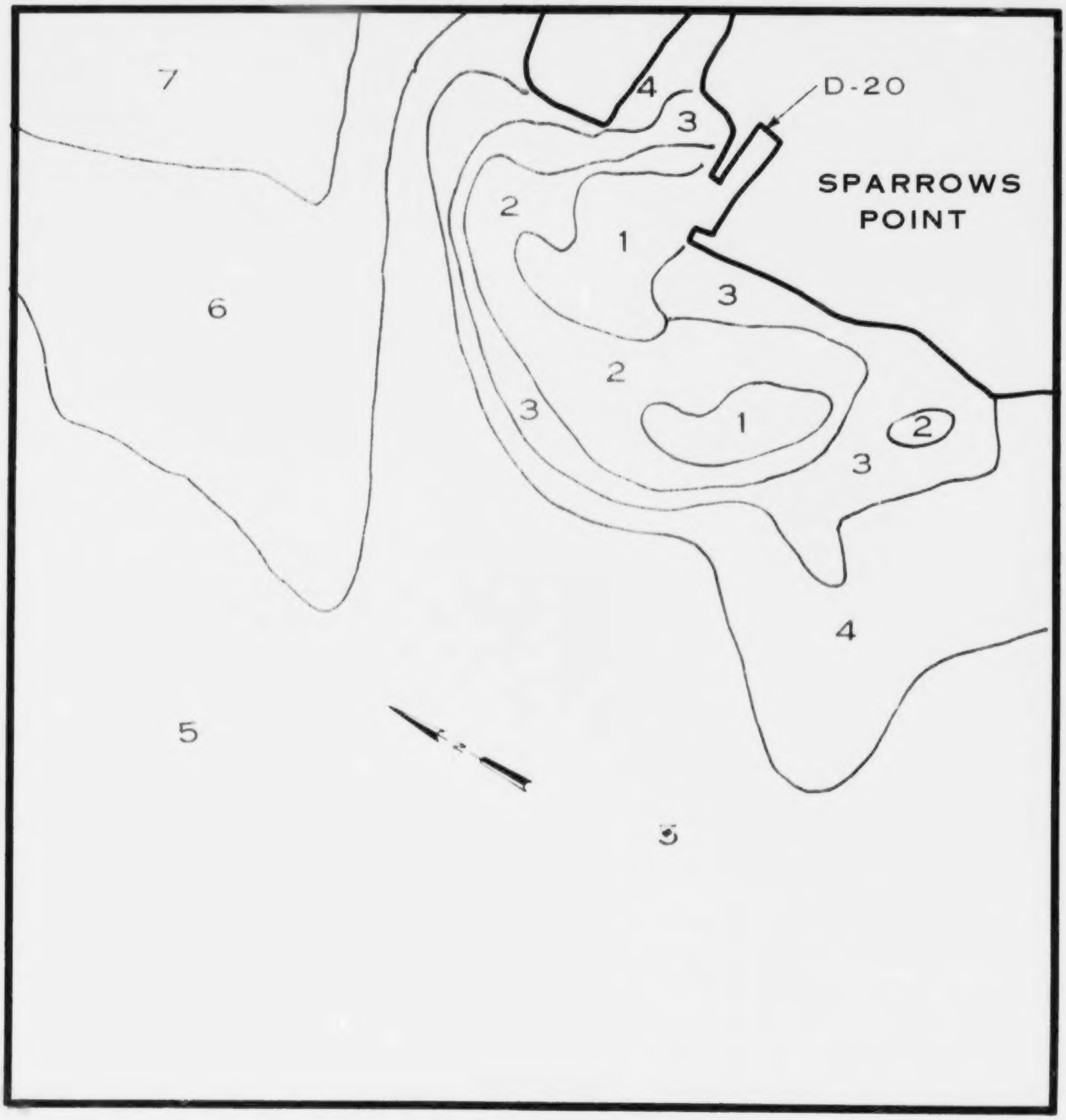

7
4
3
D-20
SPARROWS POINT
2
1
6
3
2
3
1
2
3
4
5
5

Figure V-51 Isarthermal Map - Outfalls 009, 010, 011, Bethlehem Steel Corporation, Sparrows Point

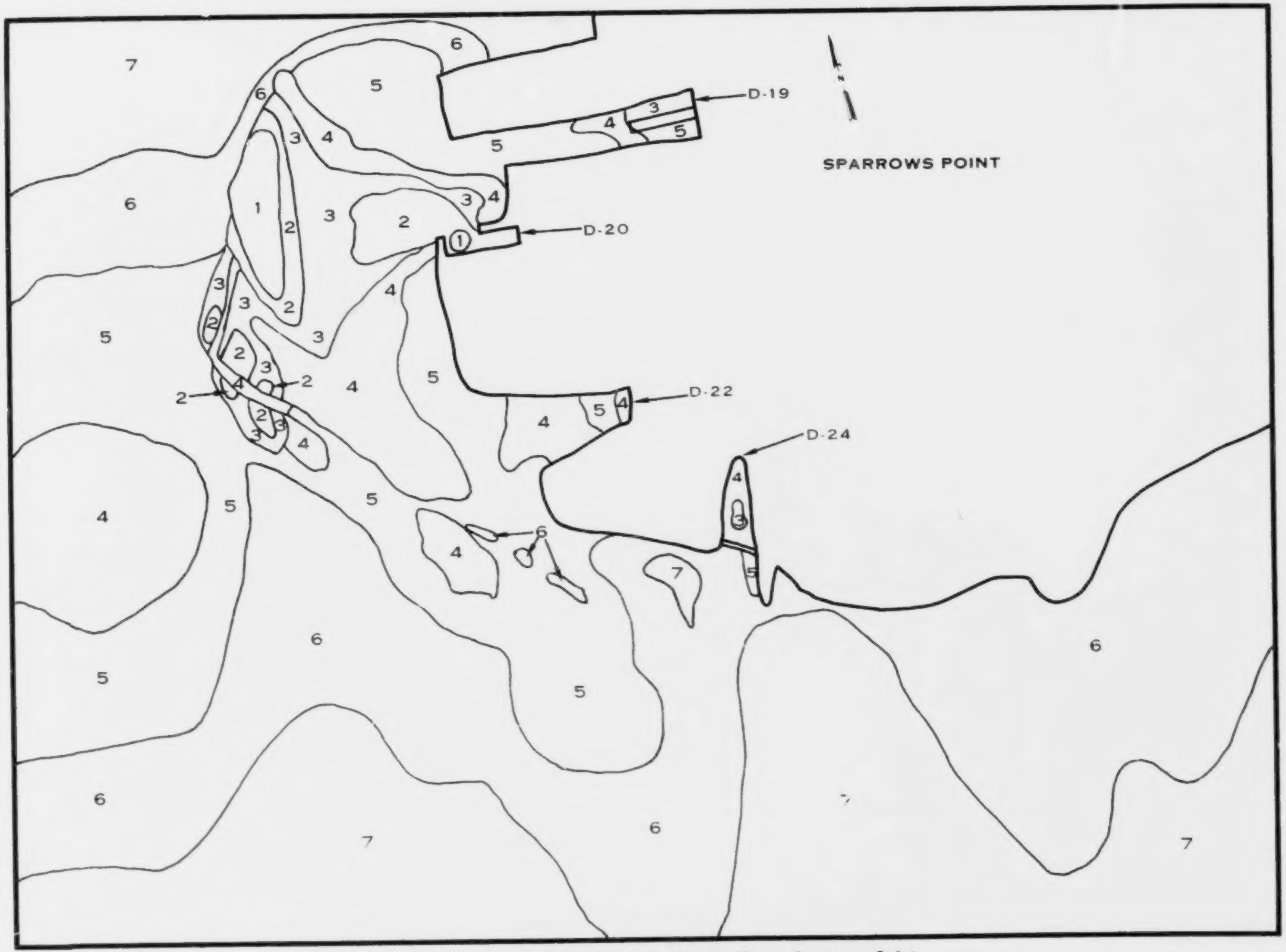

SPARROWS POINT
D-19
D-20
D-22
D-24
1
2
3
4
5
6
7

Figure V-52 Isarthermal Map - Southwest Shore, Sparrows Point

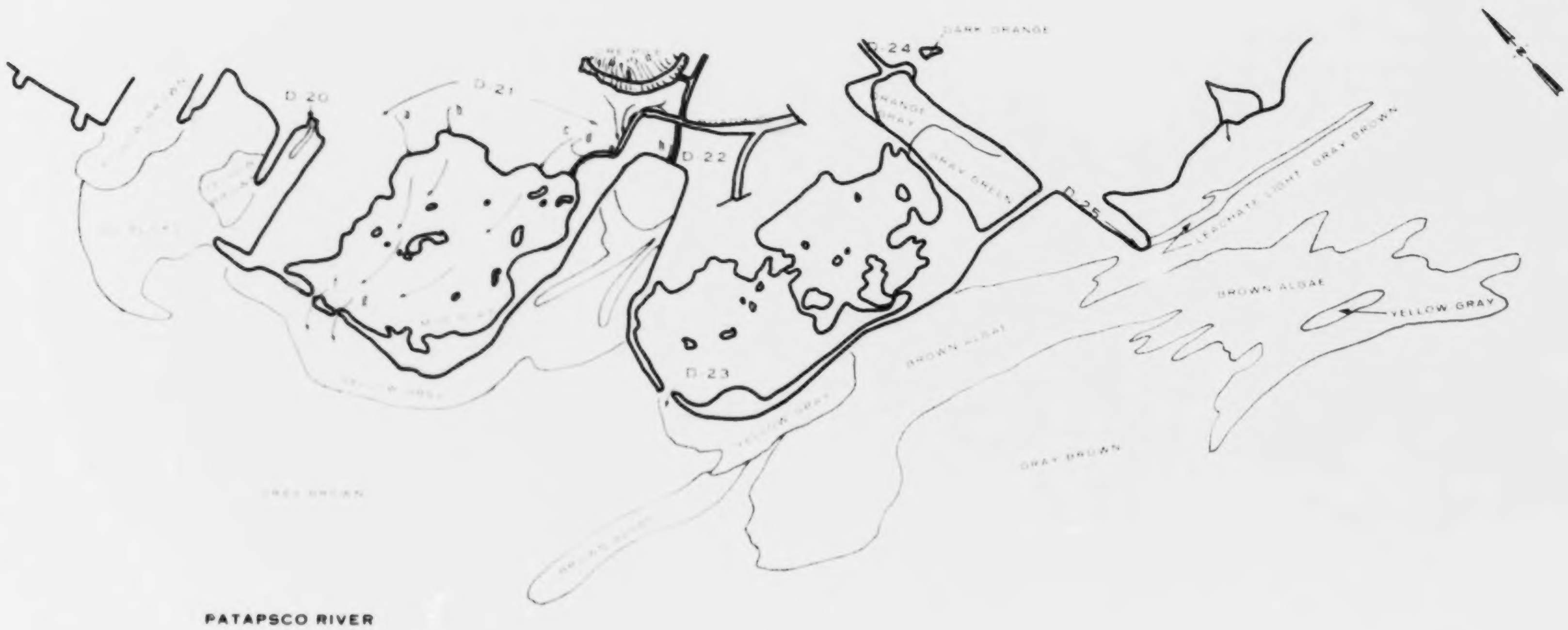

D-20
D-21
a
b
c
d
e
f
g
h
D-22
D-23
D-24
DARK ORANGE
ORANGE GRAY
GRAY GREEN
D-25
LEACHATE LIGHT - GRAY BROWN
BROWN ALGAE
YELLOW GRAY
BROWN ALGAE
YELLOW GRAY
GRAY BROWN
PATAPSCO RIVER

Figure V-53 Detailed Observations - Southwest Shore, Sparrows Point

020 also discharges to this waterway. It is a submerged line carrying a reported 530 m^3/day (0.14 mgd) of process water to the Patapsco River at an average temperature of 41°C (105°F) with a pH range from 0.3 to 2.1.

D-22 (Night)--The surface waters at the apex of this geometrical slip were estimated to be 1 to 2°C (2 to 4°F) warmer than the ambient river waters. This is shown in Figure V-49 and in the isarthermal map [Figure V-52].

D-23 (Day)--A yellow-gray turbid water was washing out of this mud flat into the Patapsco River causing a yellow-gray turbid field to be present as shown in Figure V-53.

D-24 (Day)--This small ditch was discharging an orange-gray wastewater into a lagoon [Figure V-53]. This color was present only in the upper section of the lagoon while the lower section was gray-green. There was no apparent discharge into the Patapsco River.

D-24 (Night)--The surface temperature of the water in this lagoon was greater than that of the background river water as shown in Figure V-49. There was also a small thermal field along the west side of the small peninsular projection indicative of a discharge from the lagoon to the river. The field is shown in Figure V-49 and V-52. Bethlehem Steel Corporation's Outfalls 007 and 008 were located in this small area. Outfall 007 reportedly discharges 1,200 m^3/day (0.32 mgd) of cooling water. Flow data on Outfall 008 was not available.

D-25 (Day)--A light gray-brown substance was leaching into the Patapsco River waters from this point as shown in Figures V-53 and V-54. Trucks were dumping loads of soil at the end of this point during this mission.

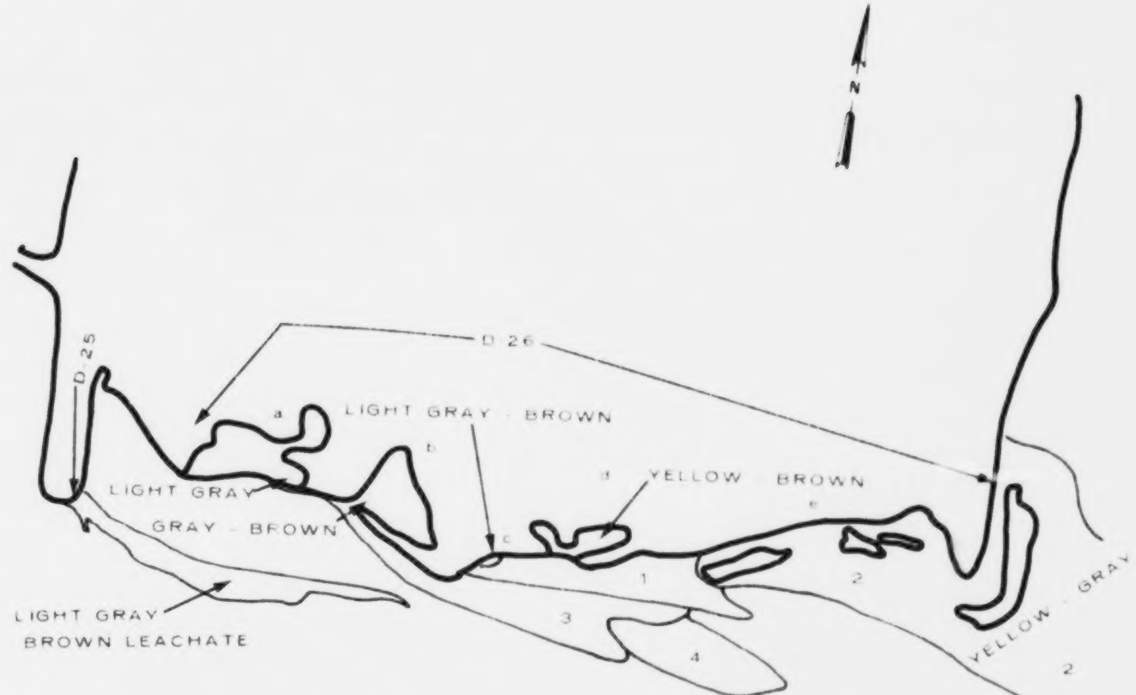

N
D-26
D-25
a
LIGHT GRAY - BROWN
b
LIGHT GRAY
GRAY - BROWN
c
d
YELLOW - BROWN
e
1
2
3
4
LIGHT GRAY
BROWN LEACHATE
YELLOW - GRAY
2
PATAPSCO RIVER

Figure V-54 Detailed Observations - South Shore, Sparrows Point

D-26 (Day)--Four areas along shore were discharging turbid water into the Patapsco River creating a moderate-sized yellow-gray turbid field as shown in Figure V-54. The numbered areas indicate the relative magnitudes of turbidity with No. 1 being the greatest. A landfill operation was in progress at the time of flight. There were small thermal discharges associated with indications "b" and "e" as shown in Figure V-47. The resultant field extended eastward because of the ebb tide condition.

D-27 (Night)--A thermal field occupied nearly all the surface waters in this dock area during the night mission. Bethlehem Steel Corporation reported a total of five outfalls in this area. They are labeled "a" through "e" in Figure V-54 and are identified as follows:

a - Outfall 002
b - Outfall 003
c - Outfall 004
d - Outfall 005
e - Outfall 006

The warm effluents from Outfalls 002 and 003 ("a" and"b") are shown in Figures V-48 and V-49. The surface water is so warm that the individual effluents from Outfalls 004, 005 and 006 were not distinguishable in the thermal data. Outfall 002 reportedly discharges 8,340 m^3/day (2.2 mgd) each of process and non-contact cooling water with an average summertime temperature of 35°C (95°F); Outfall 003 discharges 5,300 m^3/day (1.4 mgd) of non-contact cooling water at 34°C (94°F); Outfall 004 discharges 4,900 m^3/day (1.3 mgd) of noncontact cooling water at 35°C (95°F); and Outfall 006 discharges 0.8 m^3/day (200 gpd) of process water. No flow information was reported for Outfall 005.

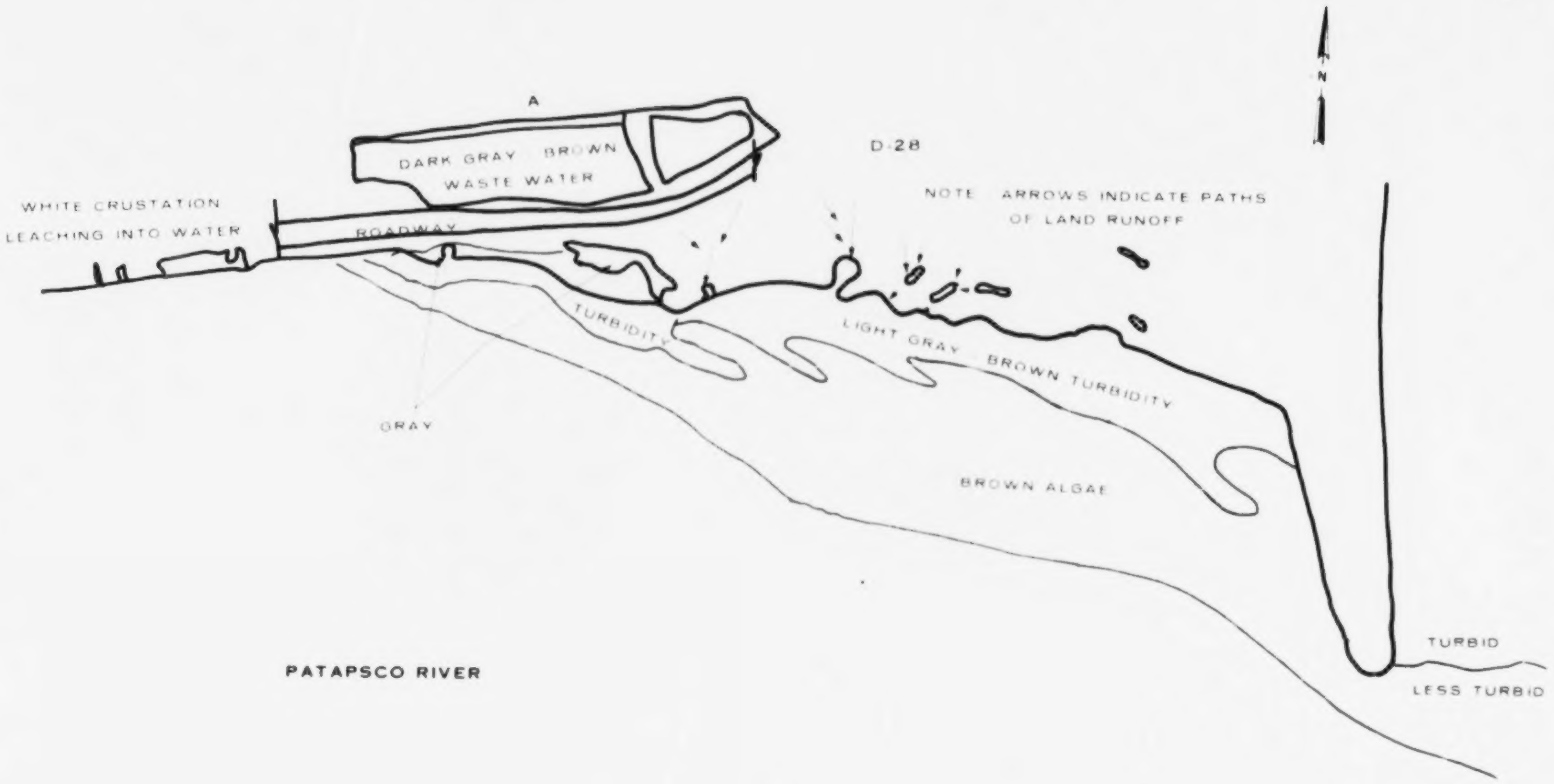

N
A
DARK GRAY BROWN
WASTE WATER
D-28
NOTE ARROWS INDICATE PATHS
OF LAND RUNOFF
WHITE CRUSTATION
LEACHING INTO WATER
ROADWAY
TURBIDITY
LIGHT GRAY BROWN TURBIDITY
GRAY
BROWN ALGAE
TURBID
LESS TURBID
PATAPSCO RIVER

Figure V-55 Detailed Observations - Southeast Shore, Sparrows Point

D-28 (Day)--Numerous locations along the southern shoreline (east side) of Sparrows Point [Figure V-55] were contributing land runoff creating a turbidity field in the Patapsco River. In the area labeled "A" there were two small ponds containing a gray-brown wastewater that were discharging to the river. The source of the wastewater could not be determined. However, there were two large rectangular lagoons across the roadway that contained a dark gray-brown wastewater. No evidence was found that indicated the presence of leaching from the lagoons under the roadway into the small ponds along shore.

D-29 (Day)--Several paths for land runoff water were recorded in this area. The main paths and small ponds affected are shown in Figure V-56.

D-30 (Day)--A dark gray-brown plume was present in Old Road Bay as a result of Bethlehem Steel Corporation's Outfall 001. The plume is shown in Figure V-56. The effluent reportedly consisted of 158,000 m^3/day (41.7 mgd) of process water and 1,490,000 m^3/day (394 mgd) of non-contact cooling water with an average discharge temperature of 33°C (92°F).

D-30 (Night)--During the night flight, Outfall 001 was causing a large thermal field in Old Road Bay as shown in Figure V-48. The field displayed a clockwise spiral circulation pattern. In Figure V-49, recorded about 12 minutes after Figure V-48, the hook on the spiral had revolved in the clockwise direction about 34° of arc. The tide was in flood phase at the time of flight. An isarthermal map [Figure V-57] of the thermal field was constructed from the image in Figure V-48. It is indicated that the warmest water (No. 1) did not come to the surface

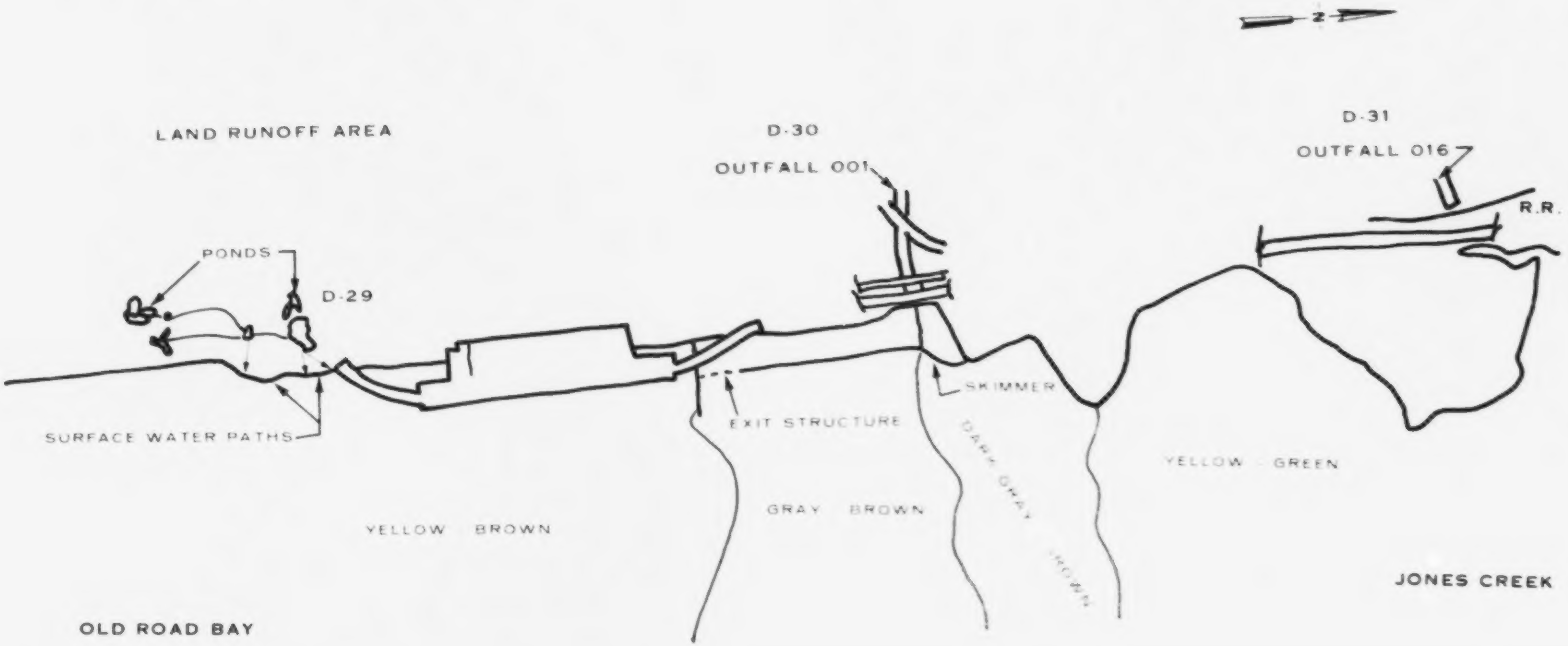

N
LAND RUNOFF AREA
PONDS
D-29
SURFACE WATER PATHS
D-30
OUTFALL 001
EXIT STRUCTURE
SKIMMER
D-31
OUTFALL 016
R.R.
YELLOW - BROWN
GRAY - BROWN
DARK GRAY - BROWN
YELLOW - GREEN
OLD ROAD BAY
JONES CREEK

Figure V-56 Detailed Observations - East Shore, Sparrows Point

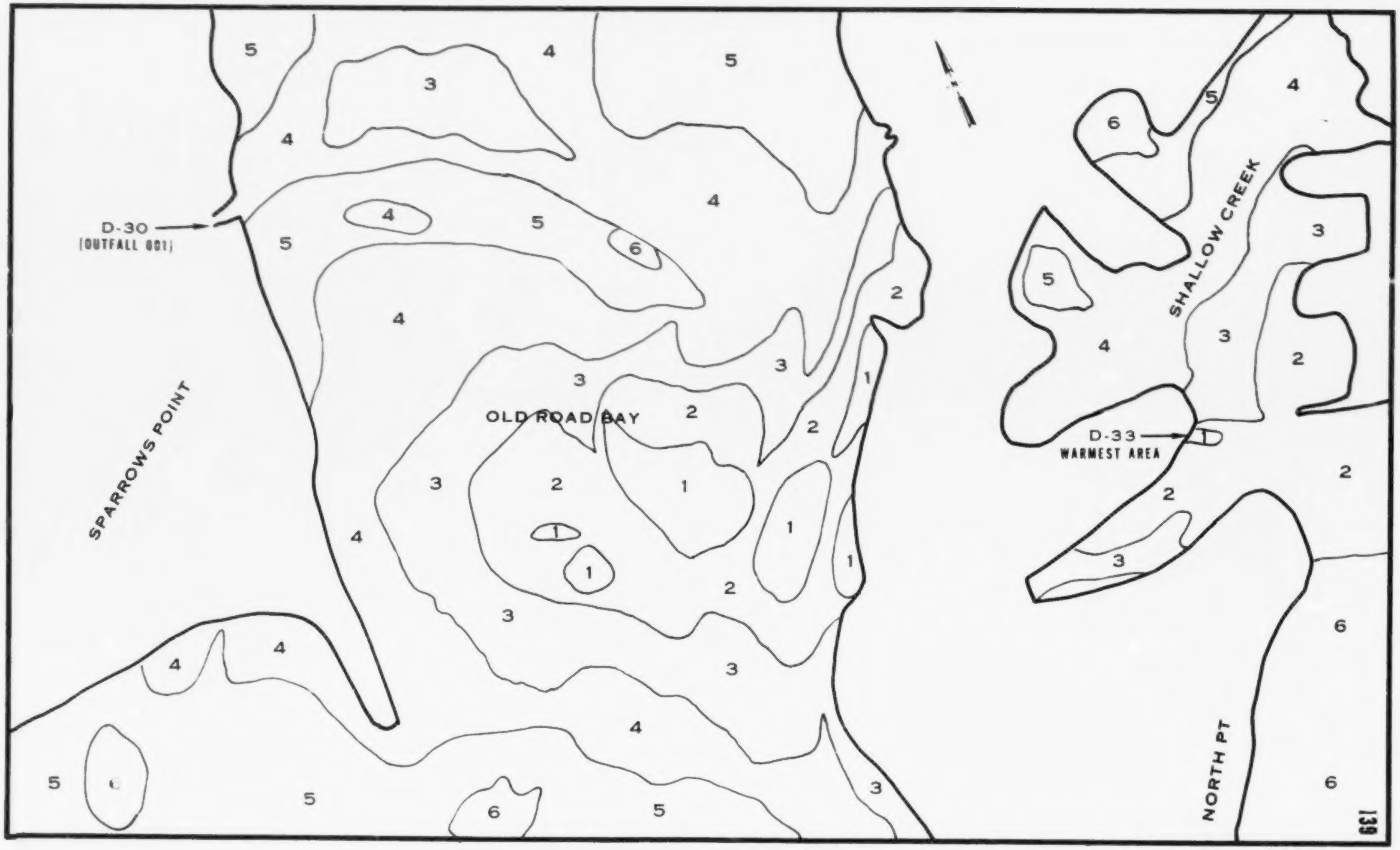

SPARROWS POINT
D-30
(OUTFALL 001)
OLD ROAD BAY
SHALLOW CREEK
D-33
WARMEST AREA
NORTH PT

Figure V-57 Isarthermal Map of Old Road Bay

until it had been reflected from the eastern shore of Old Road Bay. The areas labeled No. 1 were about 5 to 7°C (9 to 13°F) warmer than the background river waters.

D-31 (Day)--Bethlehem Steel Corporation's Outfall 016 was discharging gray-brown wastewater into Jones Creek creating a small plume [Figure V-56].

D-32 (Day)--A small light gray-brown plume was recorded adjacent to shore at this point [Figure V-38]. Bethlehem Steel Corporation's Outfall 017 was also located at this point. It had a reported flow rate of 2,650 m^3/day (0.7 mgd).

D-33 (Night)--A large thermal field extended out of this area into Chesapeake Bay as shown in Figures V-48 and V-49. The source of the warm water was not known. However, the warmest surface water temperature was located at the shore position indicated in Figure V-57. The area labeled No. 1 was estimated to be 5 to 7°C (9 to 13°F) warmer than the background waters in Chesapeake Bay, south of the thermal field in Figure V-49.

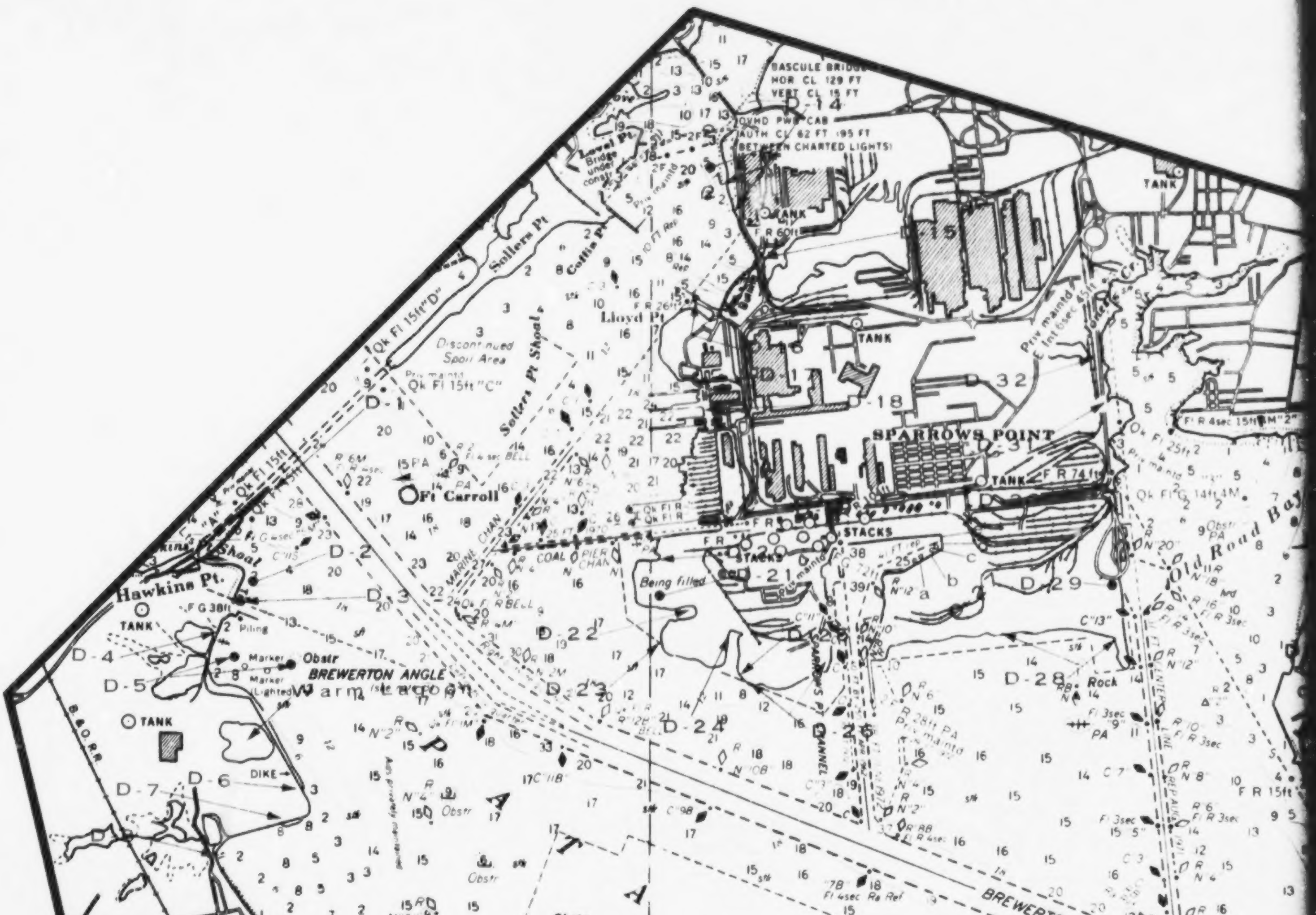
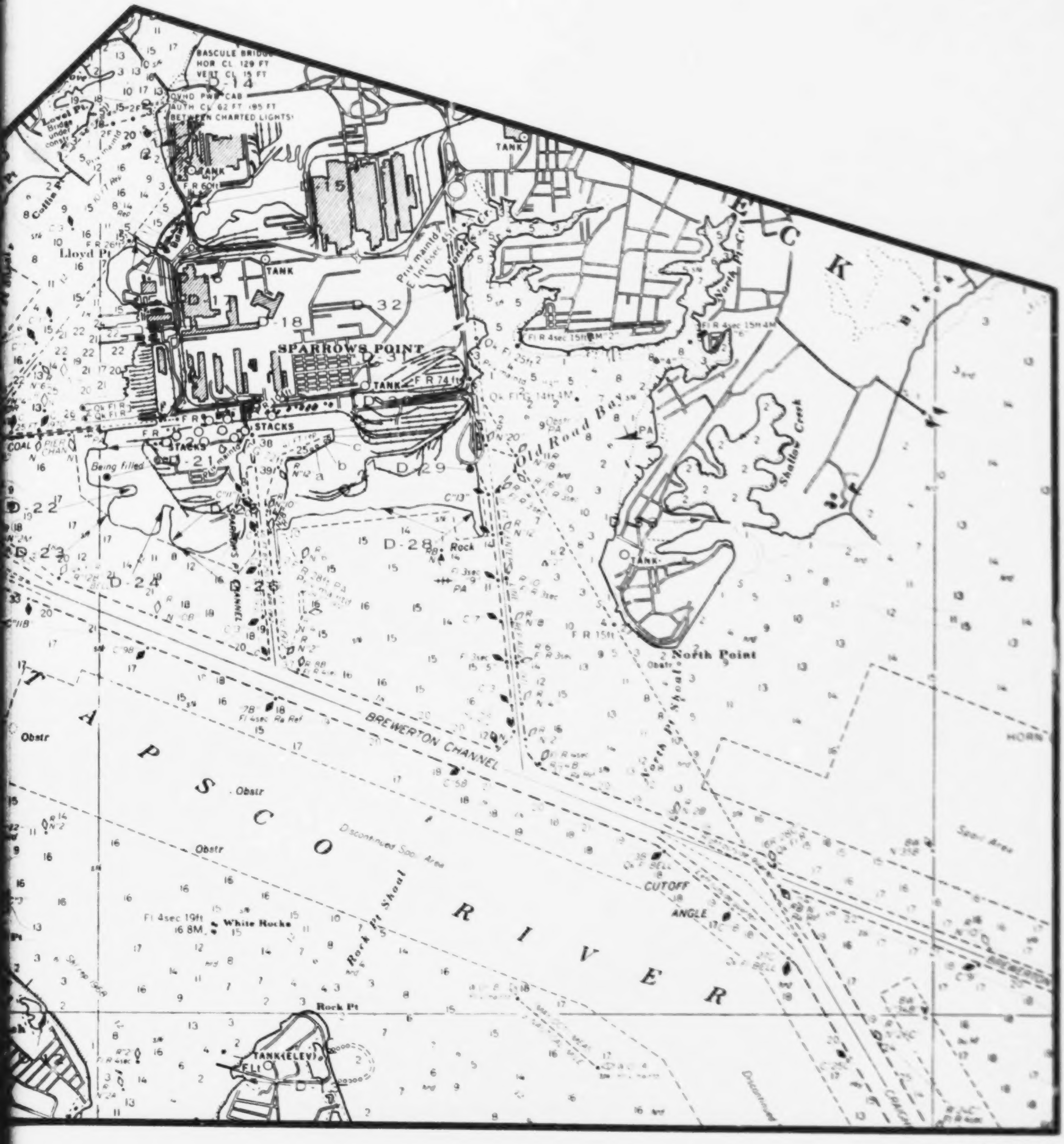

D-1
D-2
D-3
D-4
D-5
D-6
D-7
D-9
D-10
D-11
D-14
D-15
D-17
D-18
D-21
D-22
D-23
D-24
D-26
D-28
D-29
D-31
D-32
a
b
c
BASCULE BRIDGE HOR CL 129 FT VERT CL 15 FT
Sollers Pt
Sollers Pt Shoal
Lloyd Pt
Ft Carroll
Discontinued Spoil Area
SPARROWS POINT
TANK
STACKS
Being filled
Old Road Bay
Hawkins Pt.
BREWERTON ANGLE
Warm Lagoon
DIKE
Obstr
PATAPSCO RIVER
BREWERTON CHANNEL
STACK (N OF THREE)
STACK (S OF THREE)
Orchard Beach
Stony Pt
White Rocks
Rock Pt Shoal
Rock Pt
Riviera Beach
BASCULE BRIDGE HOR. CL. 40 FT. VERT. CL. 18 FT.
TANK (ELEV)

Figure V-38 Locations of Specific Observations - Area D, Oute


BASCULE BRIDGE HOR CL 129 FT VERT CL 15 FT
OVHD PWR CAB AUTH CL 62 FT 195 FT BETWEEN CHARTED LIGHTS
Lloyd Pt
Coffin Pt
TANK
D-14
D-15
D-18
D-32
SPARROWS POINT
STACKS
COAL PIER CHAN
Being filled
D-21
D-22
D-23
D-24
D-26
D-28
D-29
D-30
D-31
D-13
Old Road Bay
North Point
North Pt Shoal
Shallow Creek
BREWERTON CHANNEL
CUTOFF
ANGLE
P A T A P S C O R I V E R
White Rocks
Rock Pt Shoal
Rock Pt
TANK(ELEV)
Discontinued Spoil Area
Spoil Area
HORN
Obstr
Rock
a
b
c

V-38 Locations of Specific Observations - Area D. Outer Harbor

UPPER BACK RIVER (AREA E)

The Back River is a tidal arm of Chesapeake Bay north of Baltimore Harbor across the Patapsco River Neck. The study area encompassed the upper portions of the River as shown in Figure V-1. This area of the River is relatively shallow, averaging 1 to 2 m (3 to 6 ft) deep. A more detailed map of the study area is presented in Figure V-58, a segment of U. S. Coast and Geodetic Survey Nautical Chart 549 (Scale 1: 40,000).

General Observations

This section of the Back River was characterized by highly turbid, yellow-brown waters. No traces of brown algae were found in this area.

Specific Observations

E-1 (Day)--A submerged discharge was active during the time of the mission at the position shown in Figure V-58. The plume extended in an easterly direction about 280 m (900 ft) before dispersing. There was no significant discoloration associated with this plume in reference to the background river water. The concentration of suspended solids appeared to be higher in the plume than was present in the background river water.

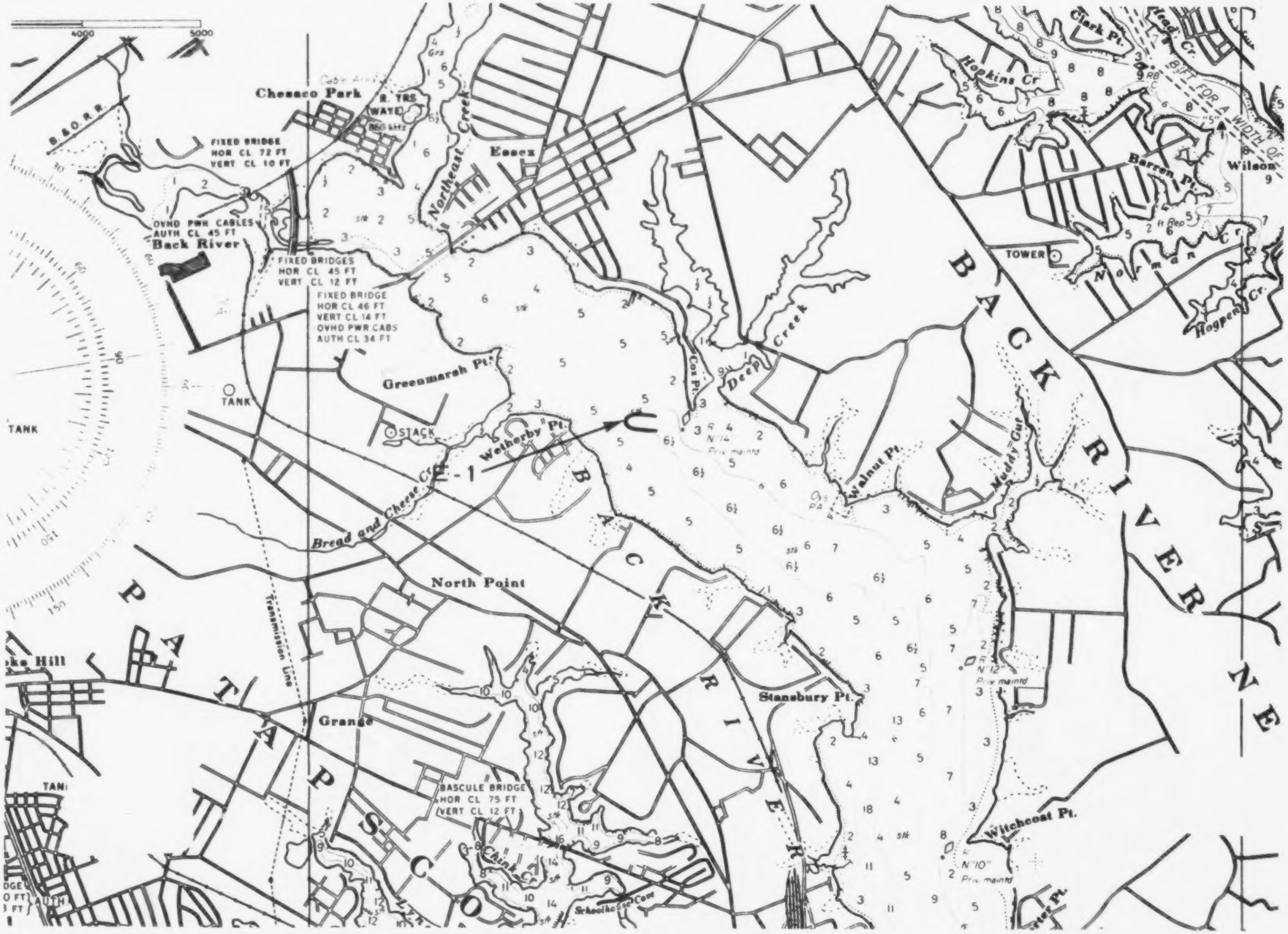

BACK RIVER NE
BACK RIVER
PATAPSCO
E-1
Chesaco Park
Essex
Northeast Creek
Back River
Greenmarsh Pt.
Wetherby Pt.
Bread and Cheese Cr.
North Point
Grange
Stansbury Pt.
Witchcoat Pt.
Walnut Pt.
Muddy Gut
Deep Creek
Cox Pt.
Hopkins Cr.
Clark Pt.
Barren Pt.
Wilson
Norman Cr.
Hogpen Cr.
China Cr.
Schoolhouse Cove
TOWER
STACK
TANK
Transmission Line
B.&O.R.R.
FIXED BRIDGE HOR CL 72 FT VERT CL 10 FT
OVHD PWR CABLES AUTH CL 45 FT
FIXED BRIDGES HOR CL 45 FT VERT CL 12 FT
FIXED BRIDGE HOR CL 46 FT VERT CL 14 FT OVHD PWR CABS AUTH CL 34 FT
BASCULE BRIDGE HOR CL 75 FT VERT CL 12 FT
4000
5000

Figure V-58 Locations of Specific Observations - Area E, Back River

VI. RESULTS AND EVALUATION OF DATA ANALYSIS WICOMICO RIVER

The Wicomico River and St. Clement Bay study area is described in Section III with the location shown in Figure III-2. These estuarine waters support active shellfish beds that were closed to commercial harvesting after detection of excessive concentrations of fecal coliform bacteria in the shellfish. Numerous hog farms and residential areas are located in the lowlands adjacent to these waters. Runoff from the hog farms and seepage from cesspools and septic tanks used for domestic sewage disposal are potential sources of bacterial contamination.

The general area was flown in order to record the presence of surface and near-surface water and to detect potential paths of movement of such water from the lowlands into the embayments. The water paths documented could provide potential means for transporting bacteria from the hog farms and sewage disposal facilities to the shellfish areas. Information on the locations of the hog farms was not available to NFIC-Denver.

Seven distinct linear flight lines were flown within the general area of the Wicomico River Basin. The geographical limits of the areas covered by these flights are shown in Figure VI-1.

Two types of infrared sensors were used to identify surface and near-surface water areas. An IRLS was used to provide a black-and-white thermal map of each area. The second sensor was a camera equipped with

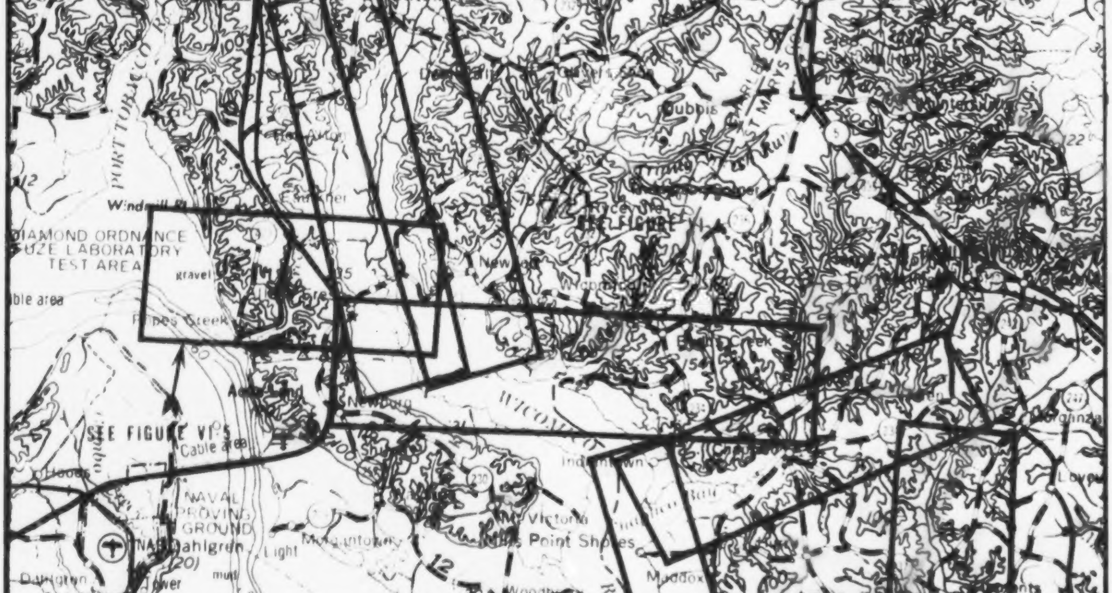

SEE FIGURE VI-7
Hughesville
SEE FIGURE
Windmill Pt
DIAMOND ORDNANCE FUZE LABORATORY TEST AREA
Popes Creek
SEE FIGURE VI-5
Cable area
NAVAL PROVING GROUND
Dahlgren
NAVAL PROVING GROUND EXTENSION
Morgantown
Tompkinsville
Rock Point
Cobb Island
SEE FIGURE VI-4
Colonial Beach
MIDDLE DANGER AREA
Gum Bar Pt
St Catherine Island
St Margaret Island
River Springs
Oakley
SEE FIGURE VI-3
St Clements Island
GEORGE WASHINGTON BIRTHPLACE NATIONAL MONUMENT
Wakefield
Danger zone
LOWER DANGER
POTOMAC
WICOMICO RIVER
Nomini Bay
BRETON BAY

Figure VI-1 Study Subareas, Wicomico River Basin

a film-filter combination (see Section III) designed to provide an infrared film transparency ideally suited to the separation of water and foliage areas.

The infrared thermal maps of six of the areas were used as base maps for locating and identifying water paths [Figures VI-2 through VI-7]. A U.S. Geological Survey topographical map was used as a base map for the seventh area [Figure VI-8]. The geographical coverage of each of these maps is shown in Figure VI-1.

Water paths identified by the infrared film are overprinted in red on the black-and-white thermal maps. Areas labeled "wet" are black on the thermal map, while the areas that are light-gray to white contain virtually no surface or near-surface water. The potential paths of water movement were observed to be quite complex, necessitating this method of data presentation.

116-A

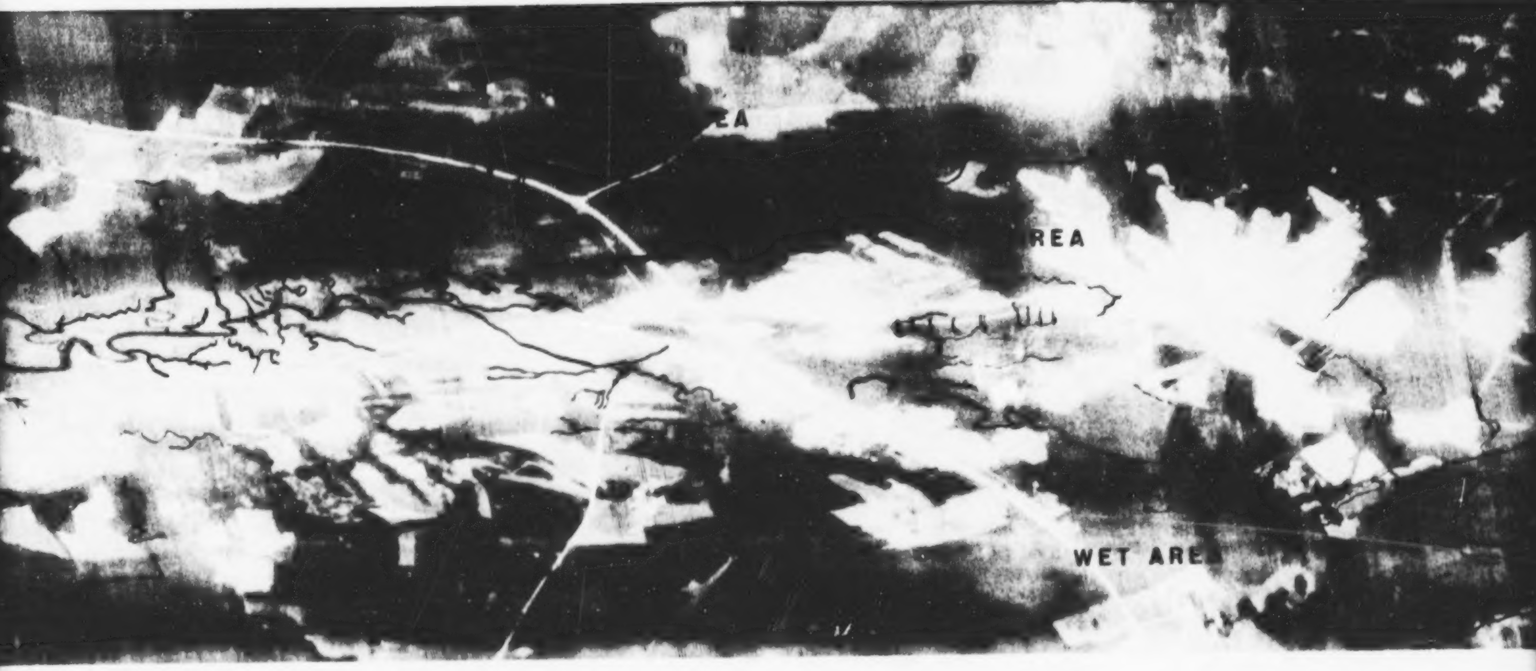

EA
REA
WET ARE

Figure VI-2 Pat

146-13

Figure VI-2 Paths of Water Movement - Chaptico Bay and Creek

146 - C

WE EA
WET AREA

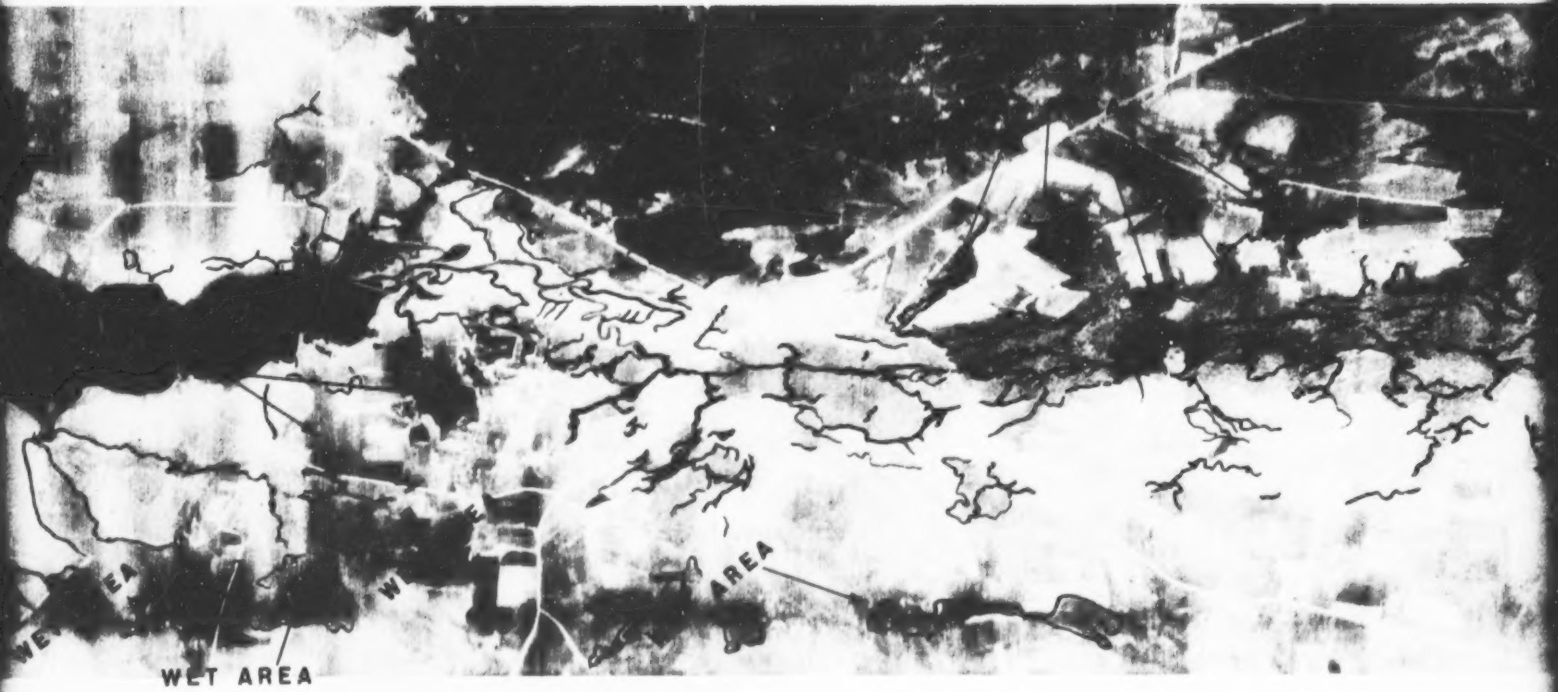
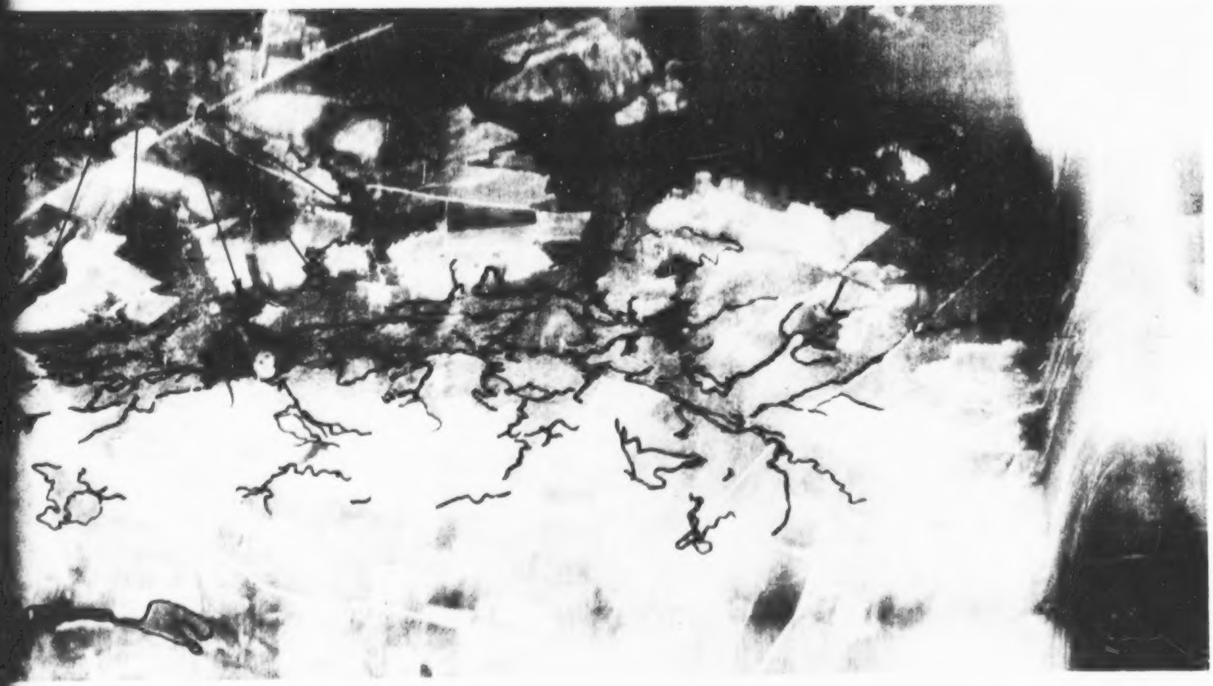

WET AREA
AREA
WET AREA

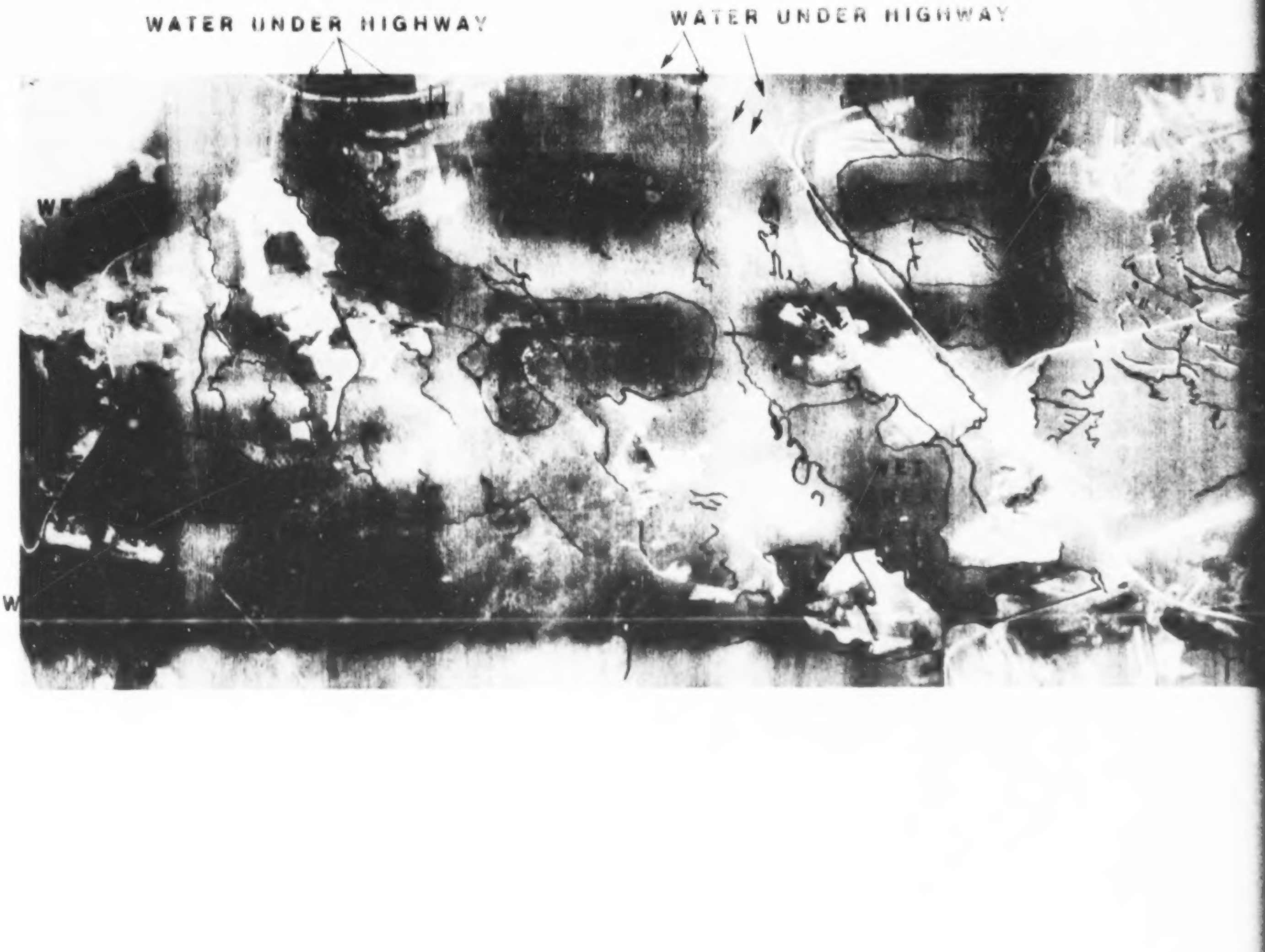
Figure VI-3 Paths of Water Movement - St. Clements D

142B



s of Water Movement - St. Clements Bay

141-C


WATER UNDER HIGHWAY
WATER UNDER HIGHWAY
WE
WET
W

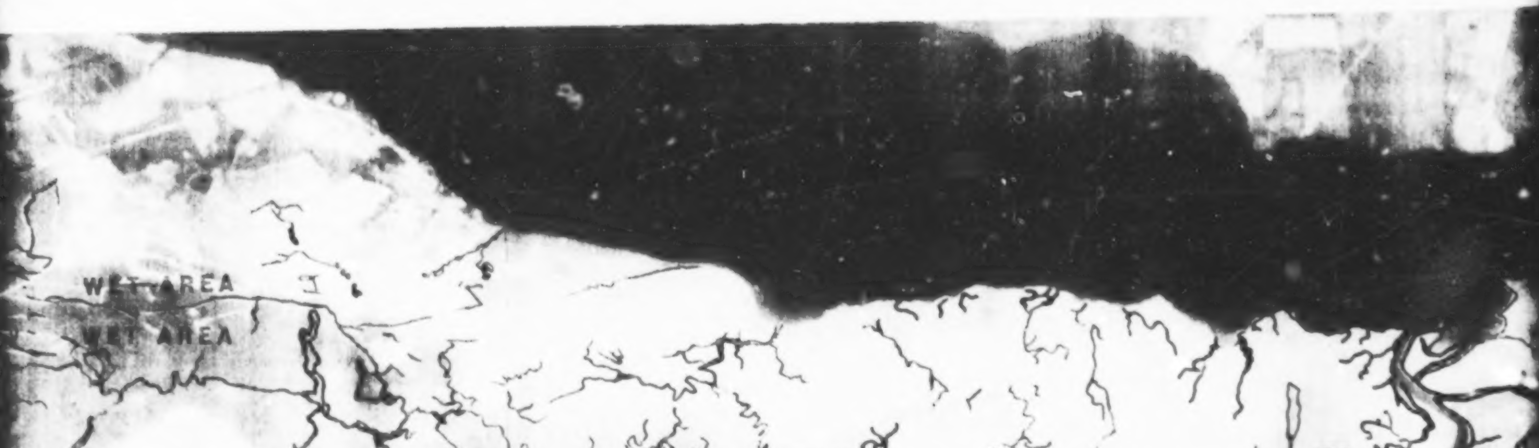
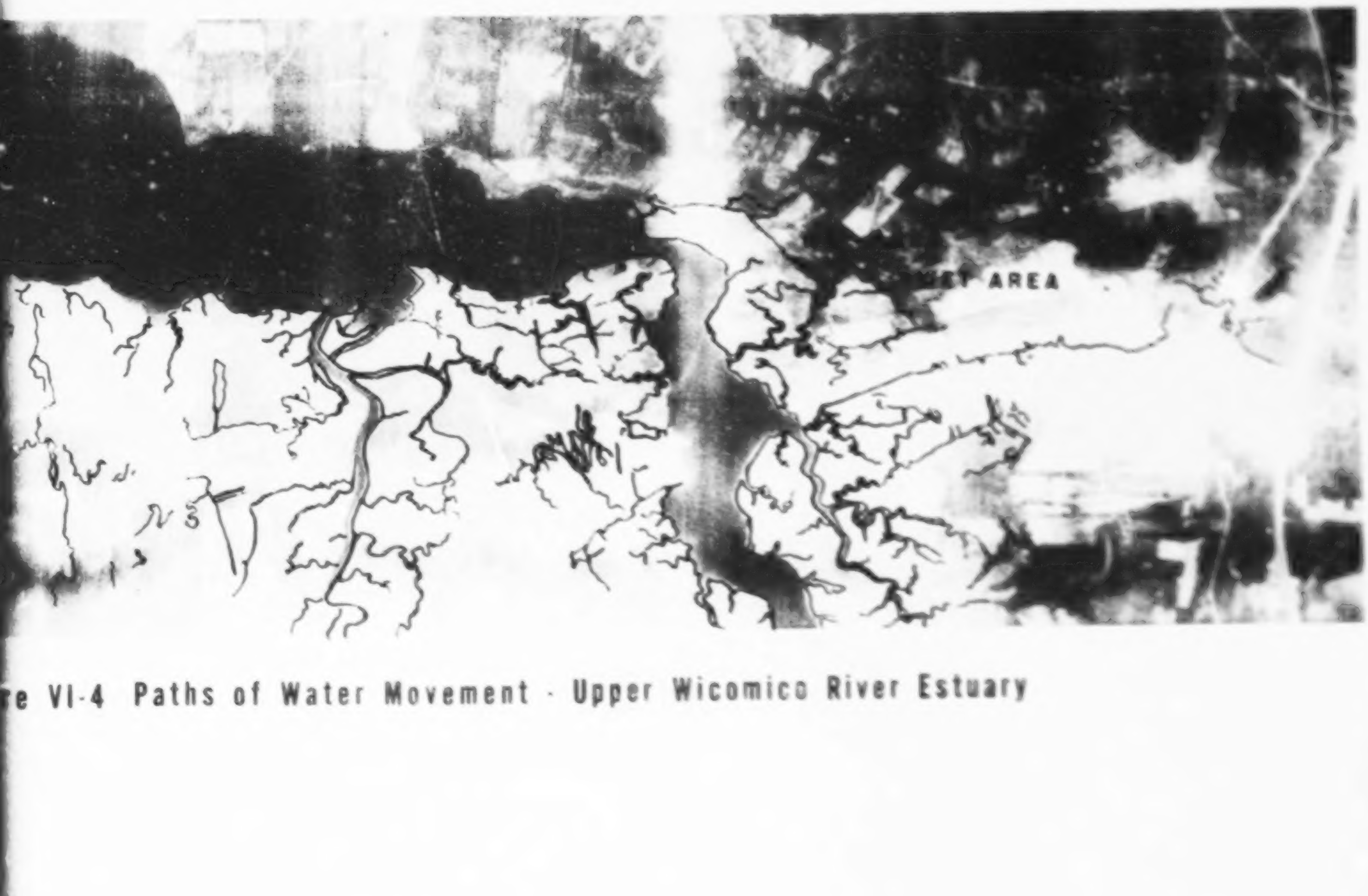

WET AREA
WET AREA
WET AREA
WATER UNDER HIGHWAY

Figure VI-4 Paths of Water Mov

141 - B



re VI-4 Paths of Water Movement - Upper Wicomico River Estuary

WET AREA
WET AREA
POTOMAC RIVER

Figur

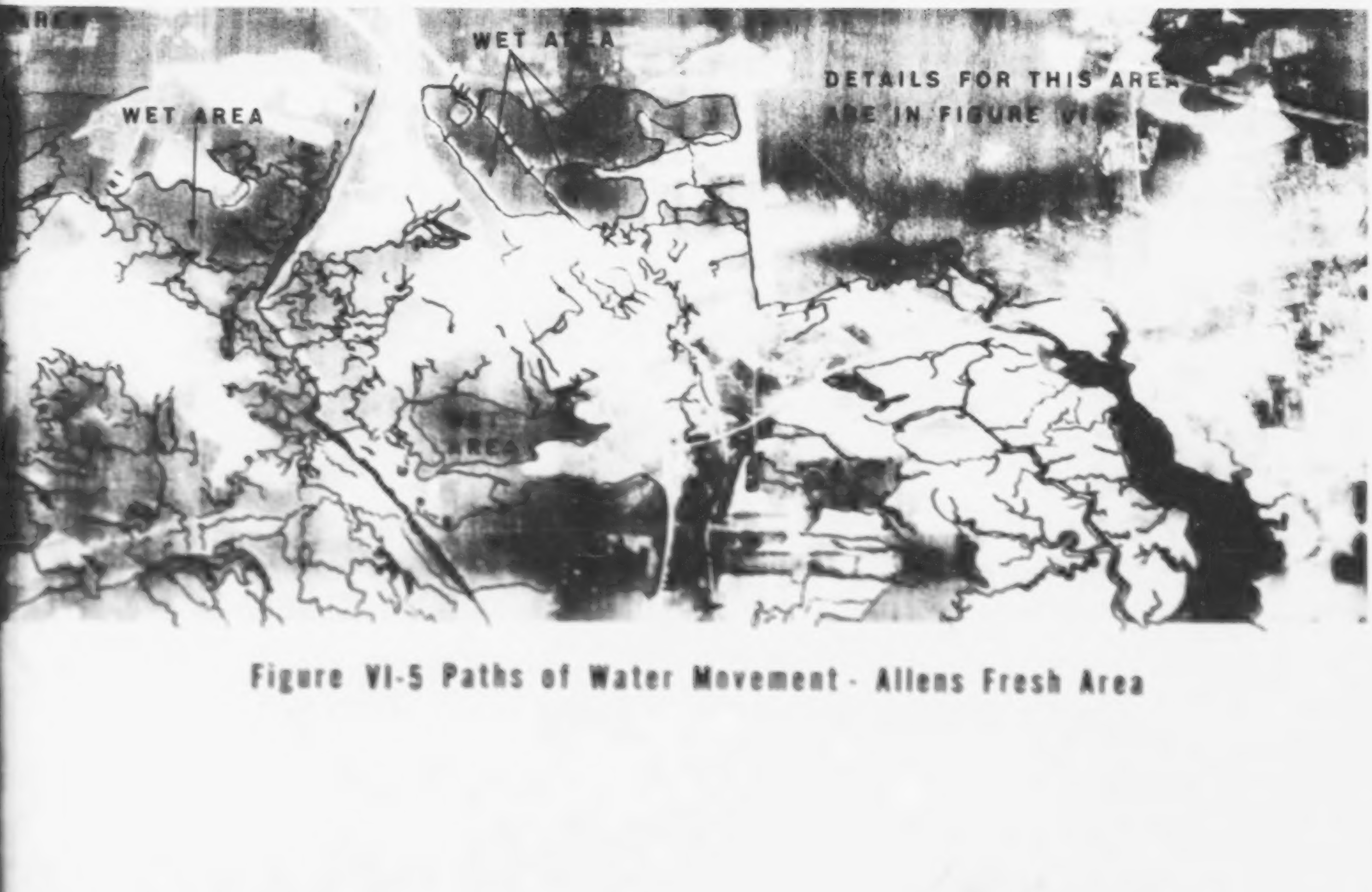

AREA
WET AREA
WET AREA
DETAILS FOR THIS AREA
ARE IN FIGURE VI-
WET AREA

Figure VI-5 Paths of Water Movement - Allens Fresh Area

AREA
WET AREA
WET AREA
AREA
WET AREA
WET AREA
WET AREA
WET AREA
WET AREA
WET AREA

Figure VI-6 Paths of W

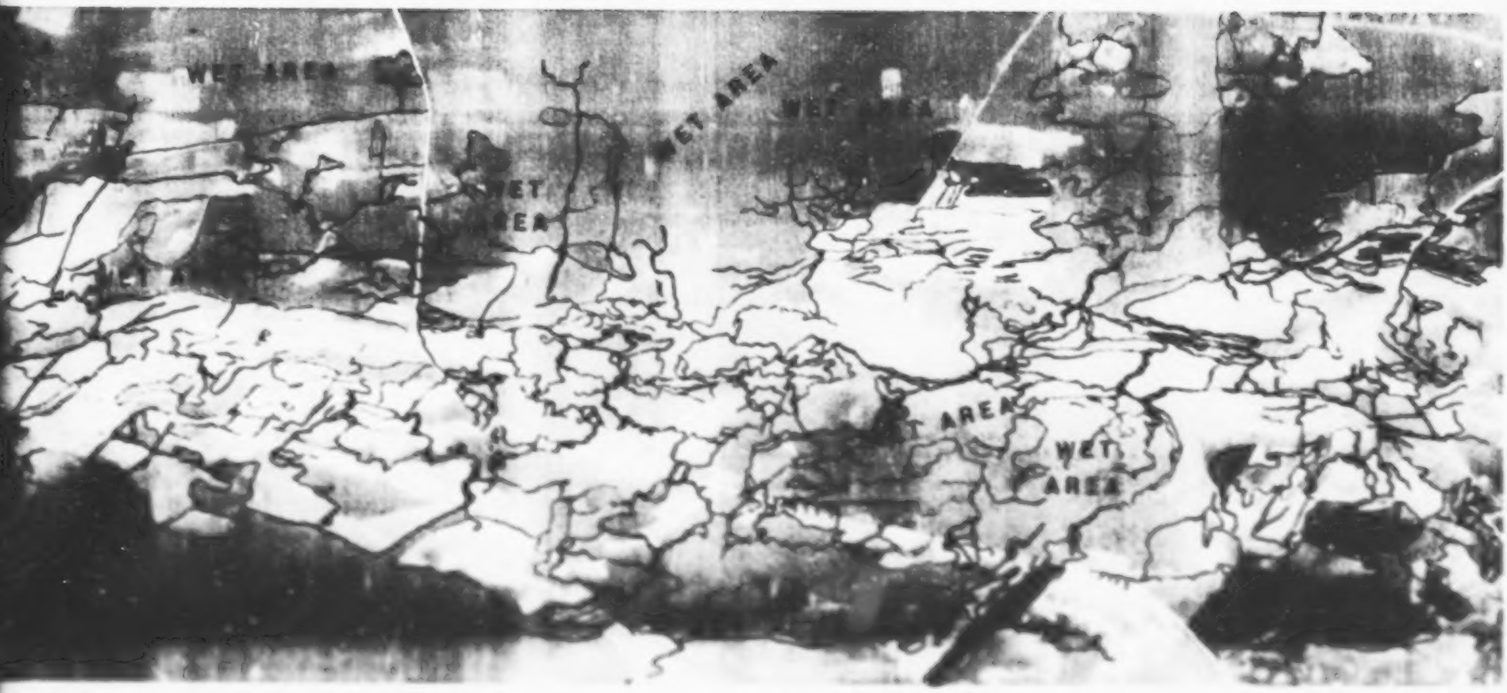

WET AREA
WET AREA
WET AREA
WET AREA
WET AREA
AREA
WET AREA

Figure VI-6 Paths of Water Movement - Kerrich and Zekiah Swamp

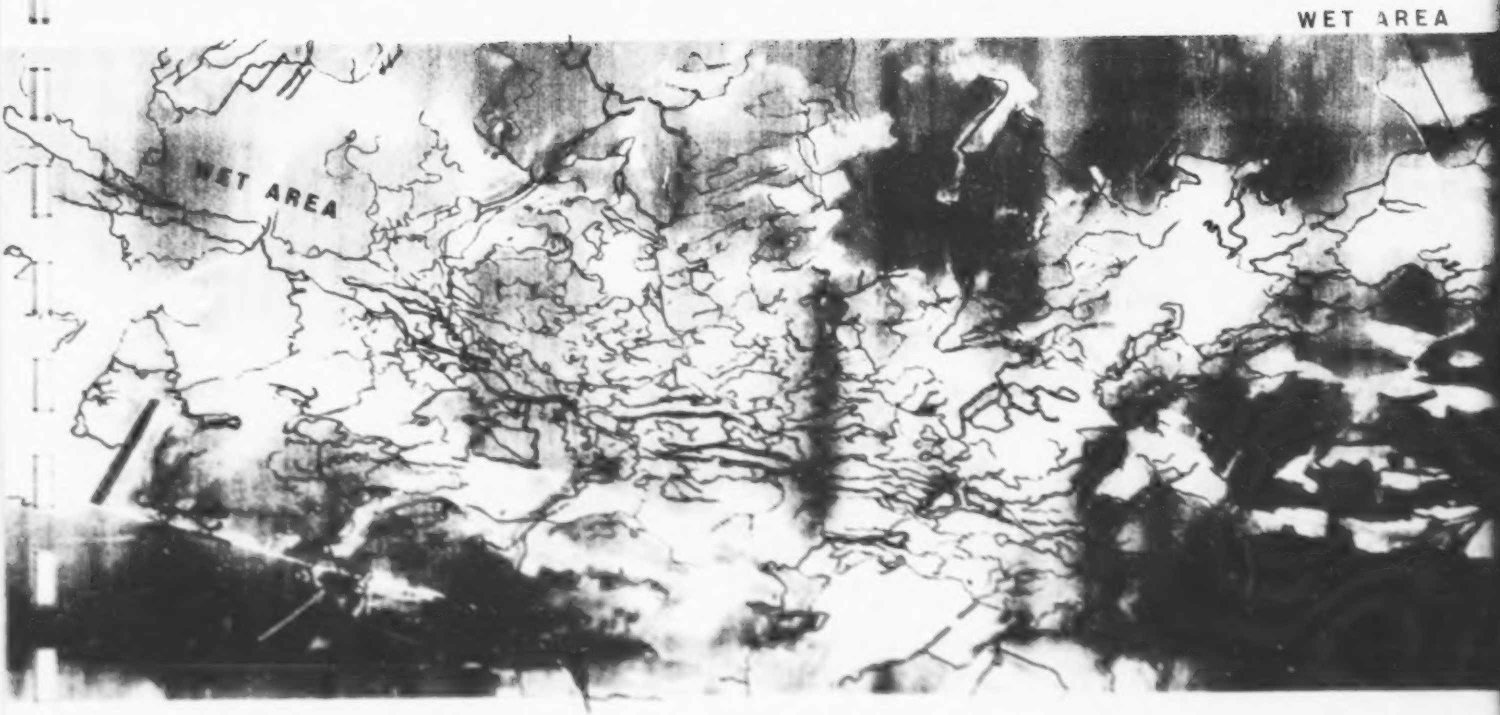

WET AREA
WET AREA

Figure VI

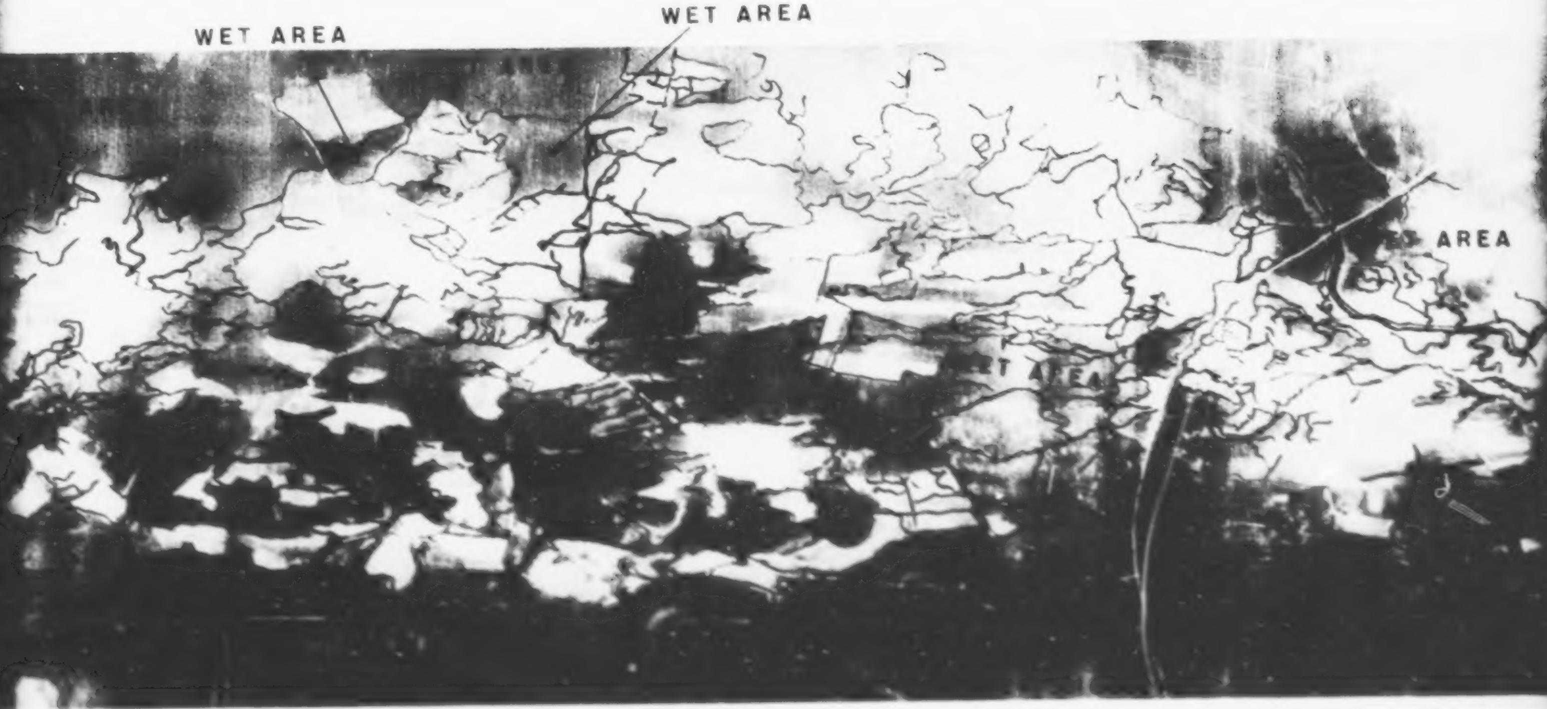
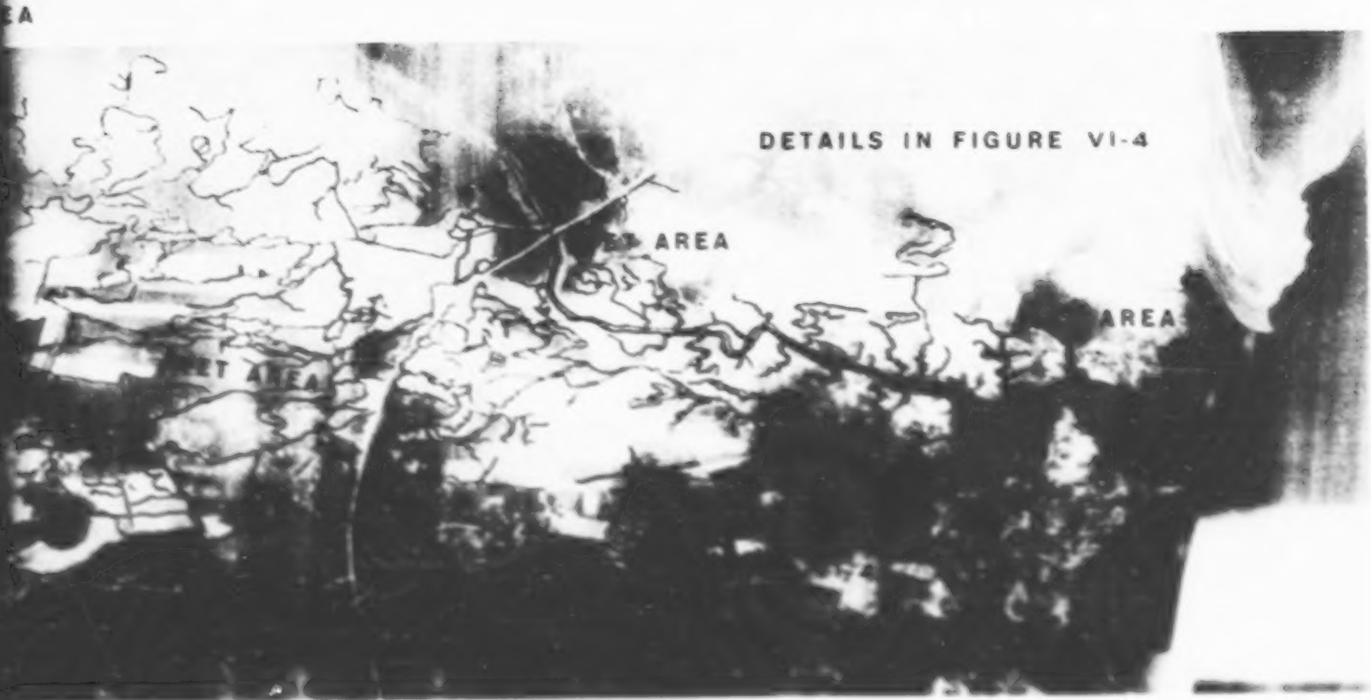
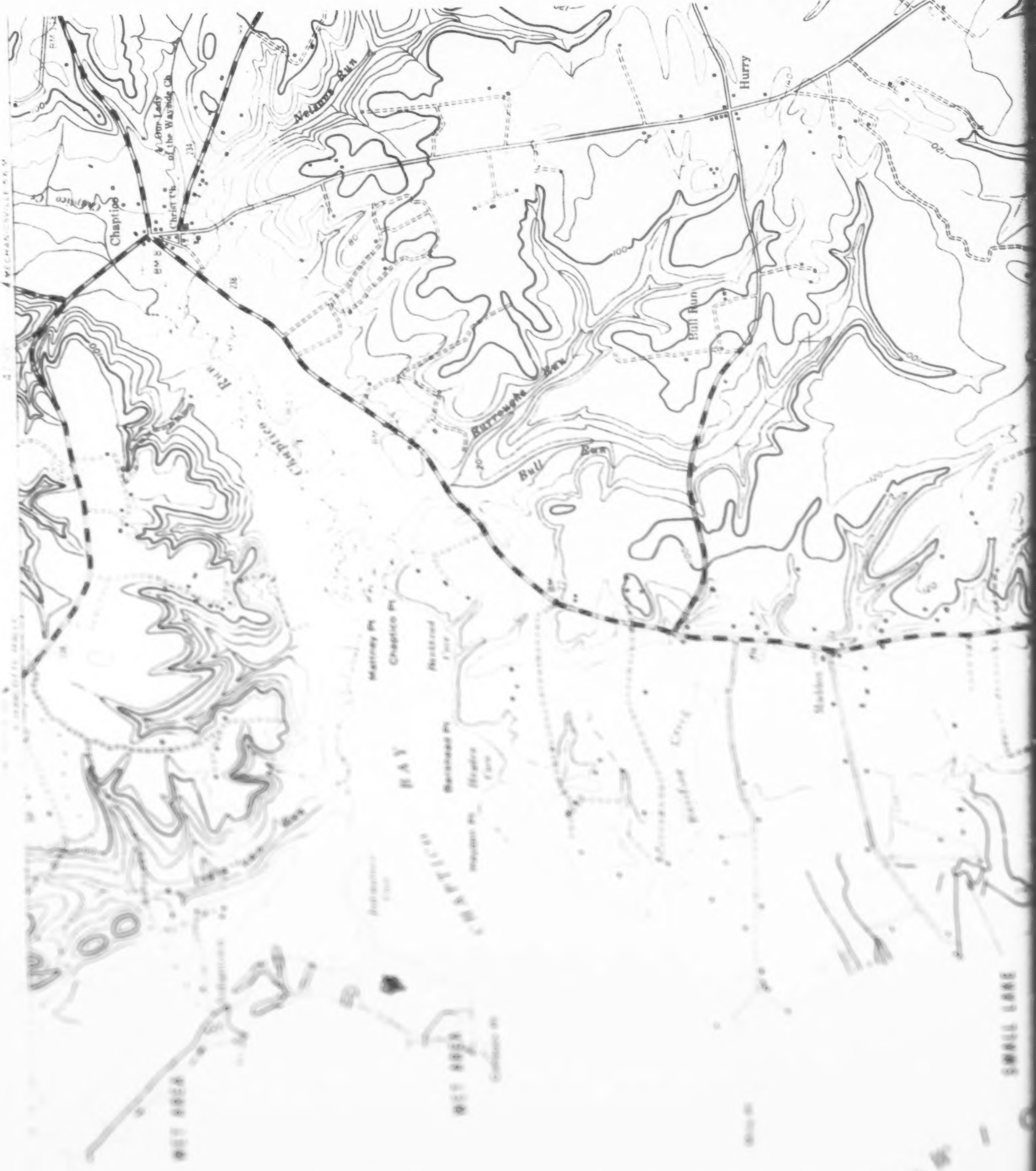

WET AREA
WET AREA
ET AREA
ET AREA

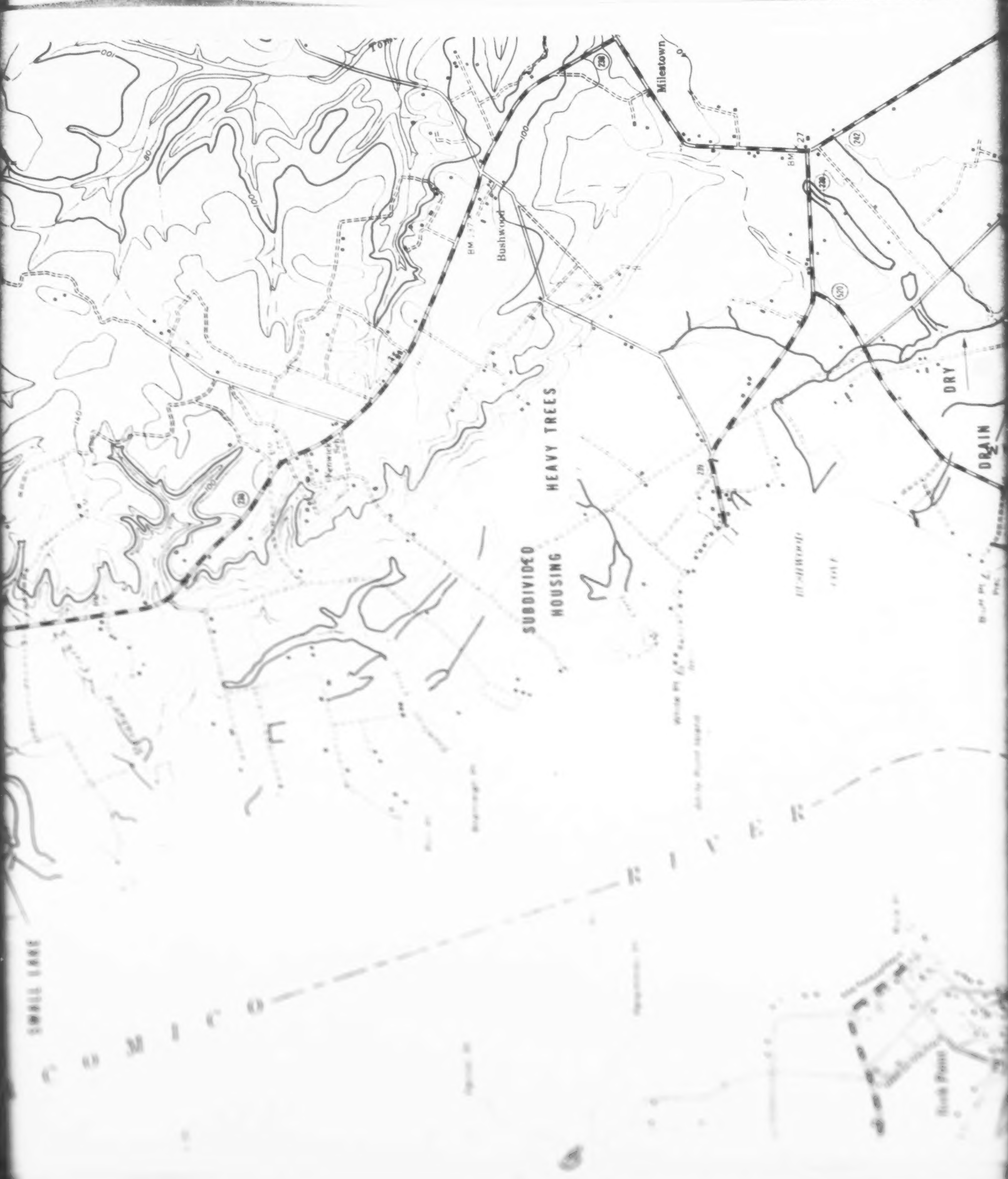
Figure VI-7 Paths of Water Movement - Zekiah and Gilbert Swamp Runs


EA
DETAILS IN FIGURE VI-4
ET AREA
AREA
ET AREA

ement - Zekiah and Gilbert Swamp Runs



Nelsons Run
Our Lady of the Wayside Ch.
Christ Ch.
Chaptico
234
238
Hurry
Bull Run
Burroughs Run
Bull Run
Chaptico Run
Chaptico Pt
HAY
CHAPTICO
WET AREA
WET AREA
SMALL LAKE
100
120


Milestown
Bushwood
BM
BM 27
Fenwick Sch
238
242
520
HEAVY TREES
SUBDIVIDED HOUSING
DRY DRAIN
COMICO RIVER
Rock Point
100
80

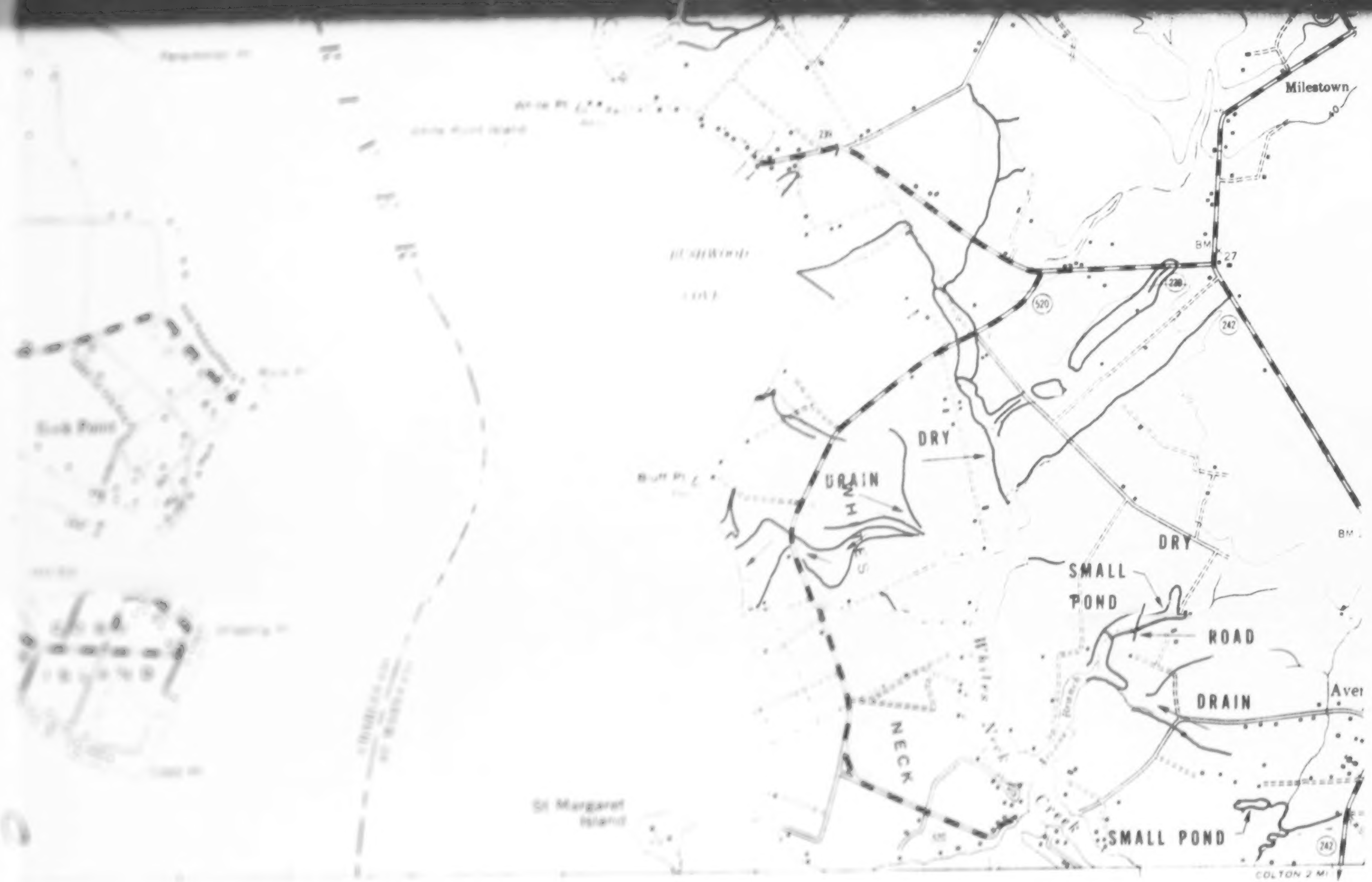

Milestown
BM
27
242
228
520
DRY
DRAIN
DRY
SMALL POND
ROAD
DRAIN
Aver
WHITES
NECK
Whites Neck Creek
SMALL POND
242
St Margaret Island
COLTON 2 MI

Figure VI - 8 Paths of Water Movement - Lower Wicomico River Estuary

VII. SATELLITE DATA ON BALTIMORE HARBOR AND UPPER CHESAPEAKE BAY

Data recorded by the Earth Resources Technology Satellite (ERTS) were obtained to provide a means for comparing the characteristics of Baltimore Harbor waters with background Chesapeake Bay waters. Imagery for three data channels (red, green and infrared I) recorded on 1 June 1973 at 1114 hours EDT and covering the entire Upper Chesapeake Bay area at an approximate scale of 1:430,000 was used for this comparison.

Figure VII-1 is a negative print of the ERTS data recorded in the green region of the optical spectrum. Spectral data of land and water are characterized by low contrast levels in this green band. In this print, dark areas are light and light areas are dark in the real world. In the Baltimore Harbor area, a turbidity field in the Inner Harbor resulted from the Patapsco River influent. This turbidity appears as a darker gray area in Figure VII-1. The level of turbidity in upper Northwest Harbor was also significant. A large discolored area in Outer Harbor extended from Hawkins Point into Chesapeake Bay. The upper reaches of Back River were significantly discolored. Patches of discoloration were recorded in Chesapeake Bay and in the delta of the Susquehanna River.

The land-to-water contrast is far greater in the ERTS red channel (Figure VII-2) than in the green; dark water areas are more pronounced, indicating the presence of suspended sediment. Discolored areas in the Patapsco River, upper Northwest Harbor and the Hawkins Point areas noted in the green channel data were more pronounced in the red channel imagery.

Scale 1 : 430,000

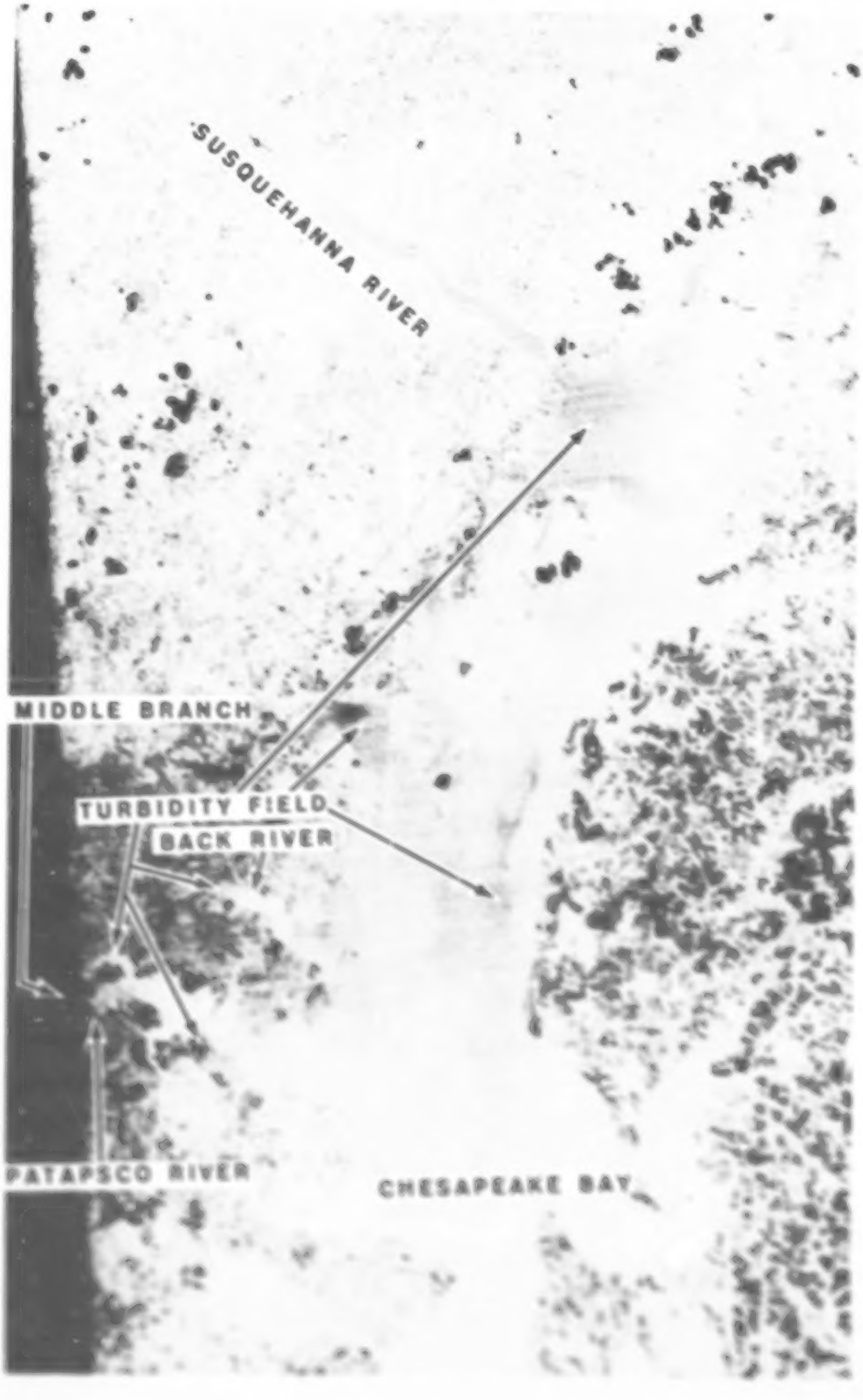

SUSQUEHANNA RIVER
MIDDLE BRANCH
TURBIDITY FIELD
BACK RIVER
PATAPSCO RIVER
CHESAPEAKE BAY

Figure VII-I Upper Chesapeake Bay [Satellite Data - Green Channel]

Scale 1 : 430.000

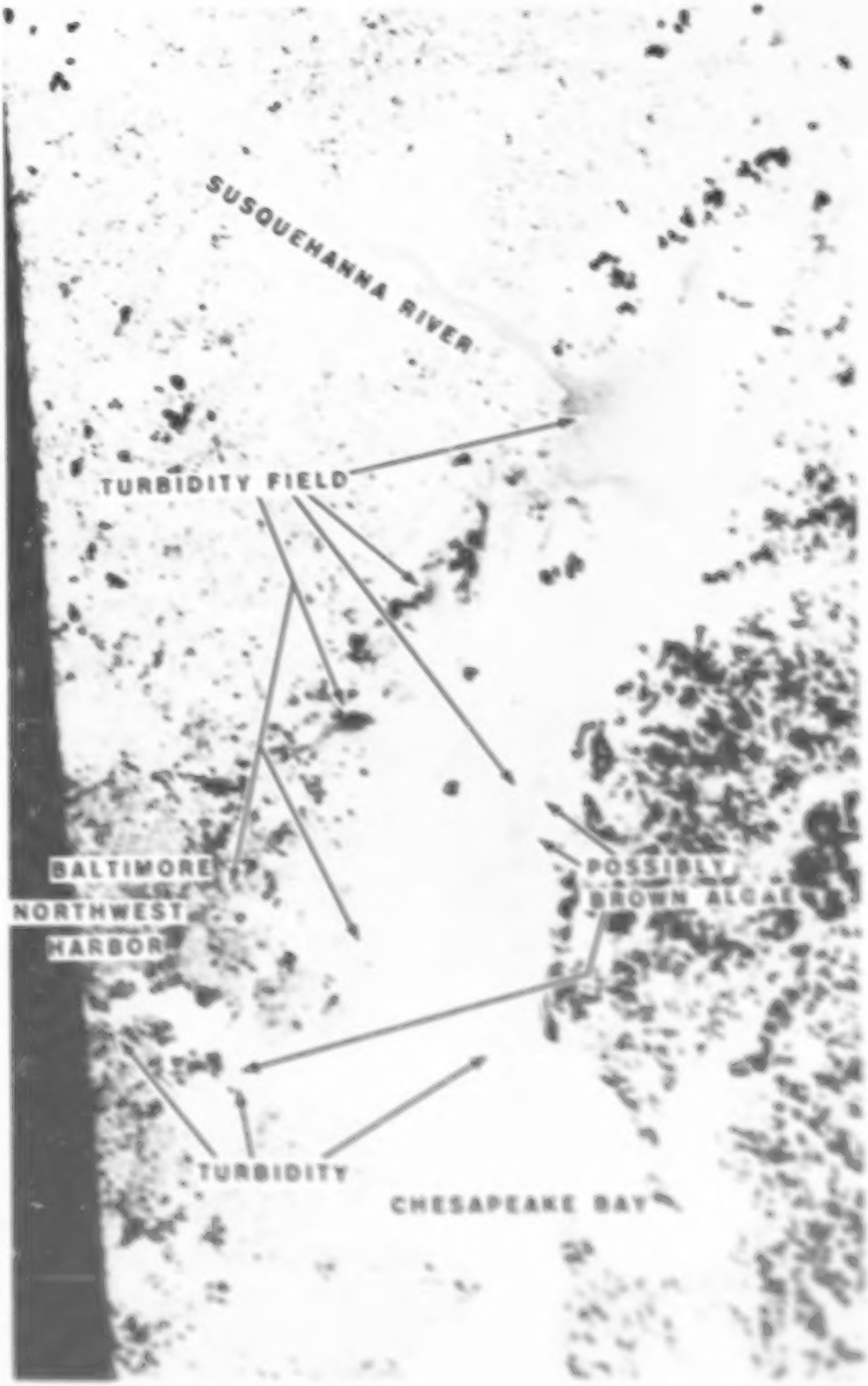

SUSQUEHANNA RIVER
TURBIDITY FIELD
BALTIMORE
NORTHWEST
HARBOR
POSSIBLY
BROWN ALGAE
TURBIDITY
CHESAPEAKE BAY

Figure VII-2 Upper Chesapeake Bay (Satellite Data - Red Channel

Of interest is a white area extending from Outer Harbor nearly across Chesapeake Bay. The cause of this color variance is not known.

In Figure VII-3, the first near-infrared channel with a bandwidth of 0.7 to 0.8 microns, there were small areas of discoloration near Hawkins Point and in Old Road Bay adjacent to Sparrows Point, and a trace in upper Northwest Harbor. Such discoloration is usually indicative of the presence of chlorophyll. As reported in Chapter V, there were large amounts of brown algae present in these areas about three weeks prior to the date of this image. There were also areas of discoloration in the Chesapeake Bay and in the Susquehanna River delta. There was no sign of discoloration in data recorded on Channel 7, the second near-infrared channel. Channel 7 data are therefore not presented in this report.

Scale 1 : 430,000

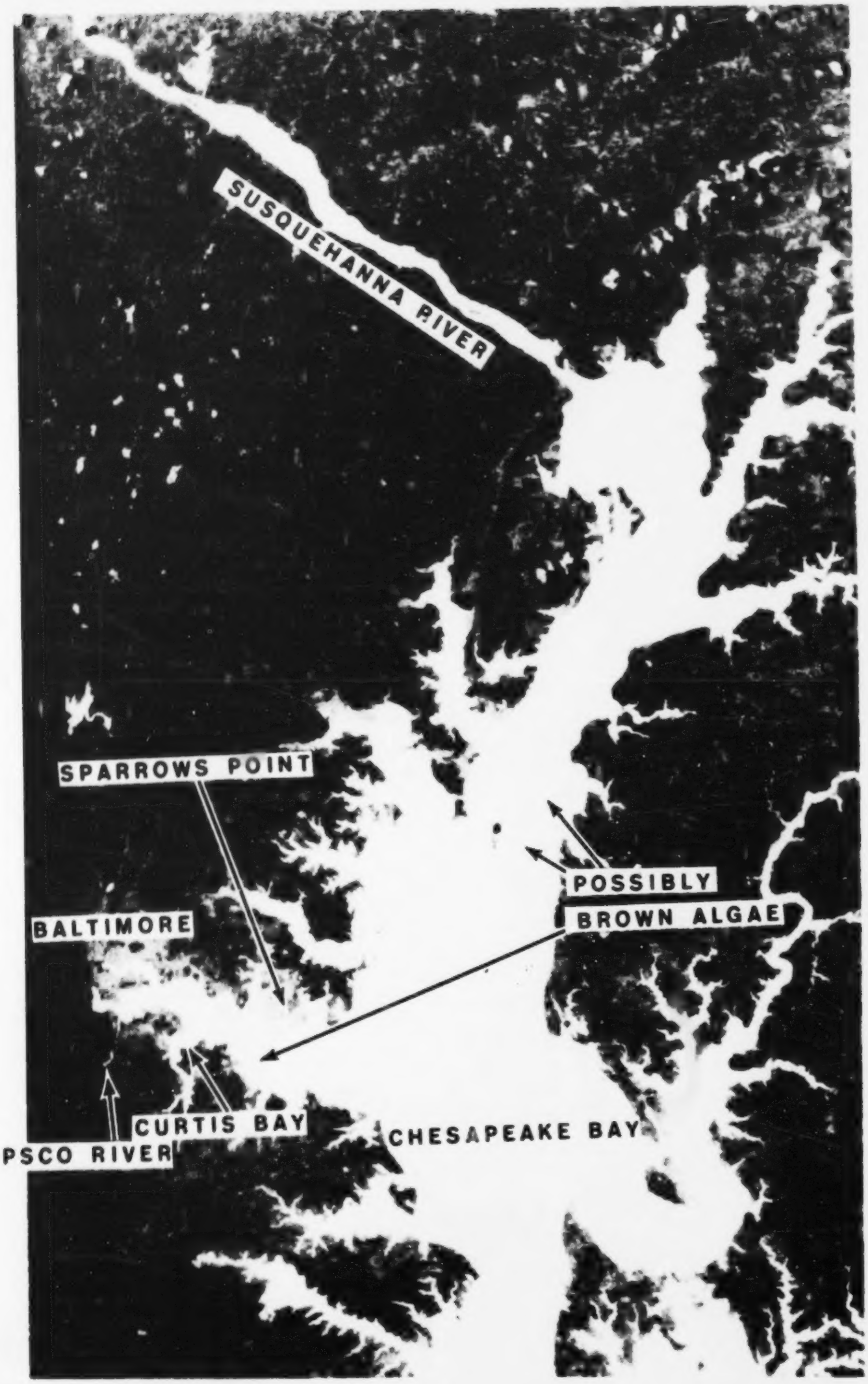

SUSQUEHANNA RIVER
SPARROWS POINT
POSSIBLY
BROWN ALGAE
BALTIMORE
CURTIS BAY
PATAPSCO RIVER
CHESAPEAKE BAY

Figure VII -3 Upper Chesapeake Bay (Satellite Data - Infrared I Channel)

APPENDIX A

FILM SPECTRAL SENSITIVITY DATA

OPTICAL FILTER TRANSMITTANCE DATA

The spectral curves for each film and optical filter used during this reconnaissance program are provided on the following pages:

i) SO-397 with HF3/HF5 filter combination

ii) 2403 with 47A

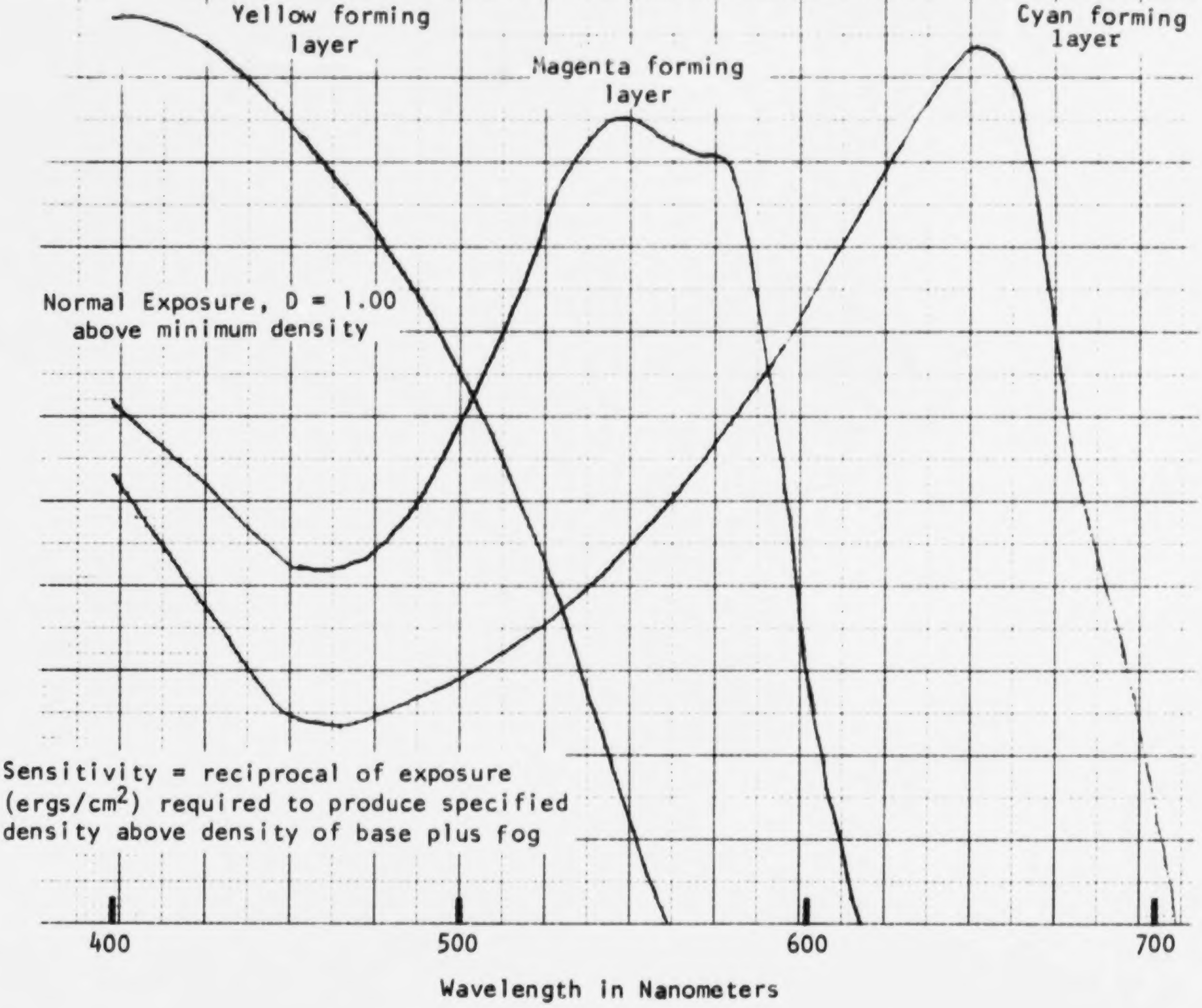
iii) 2443 with 16.

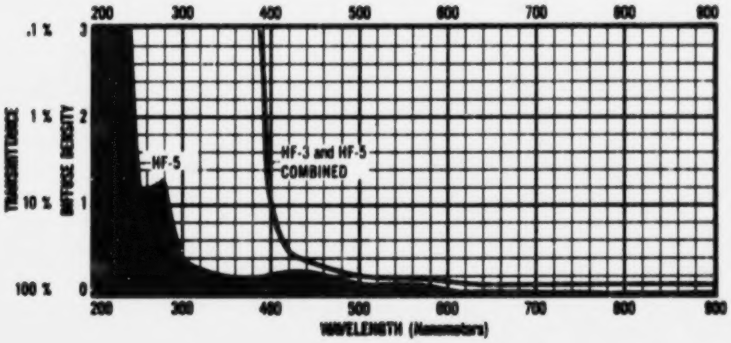
In order to obtain the optical band width B (λ) of each film-filter combination let $F(\lambda)$ be the transmittance function of the respective filter and $S(\lambda)$ be the spectral sensitivity function for the particular film. Then

$$B(\lambda) = \int_{\lambda 1}^{\lambda 2} S(\lambda)\ F(\lambda)\ d\lambda.$$

160

Kodak Ektachrome EF Aerographic Film
SO-397 Development Process EA-5





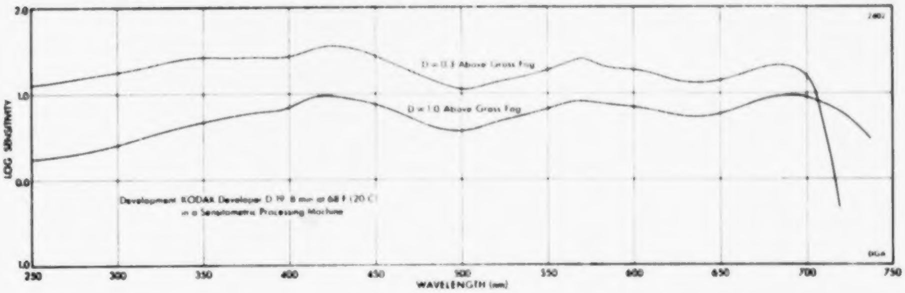
HF-3 and HF-5

AAB*

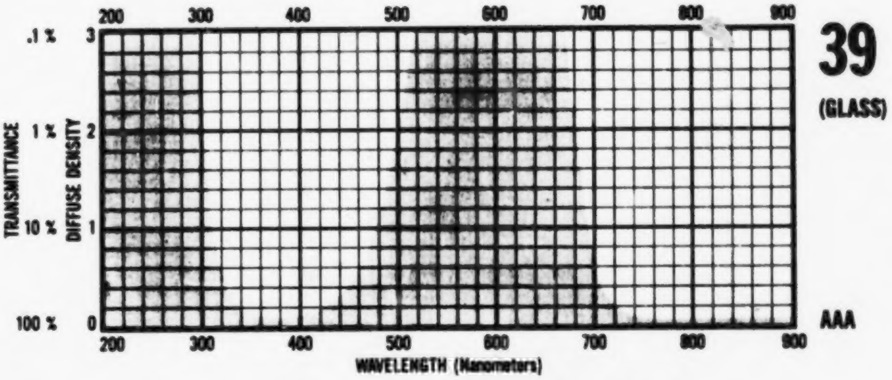
KODAK PLUS-X AEROGRAPHIC Film 2402
(ESTAR Base)

Spectral Sensitivity Curves:

D-19



Sensitivity = Reciprocal of the exposure in ergs/cm² required to produce the indicated density (D) above gross fog.



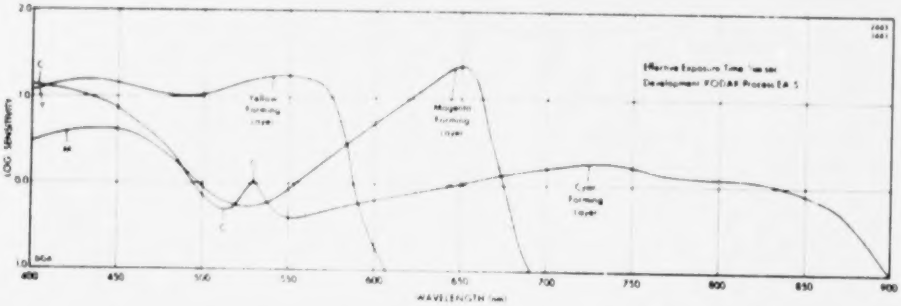
Blue. Glass contrast filter for printing motion-picture duplicates.

KODAK AEROCHROME Infrared Film 2443
(ESTAR Base)

KODAK AEROCHROME Infrared Film 3443
(ESTAR Thin Base)

Critical users of these two films should determine the actual sensitometric characteristics of their particular batch of film by using their own specialized techniques. The keeping conditions for these films have an effect on their sensitometric response.

Spectral Sensitivity Curves:

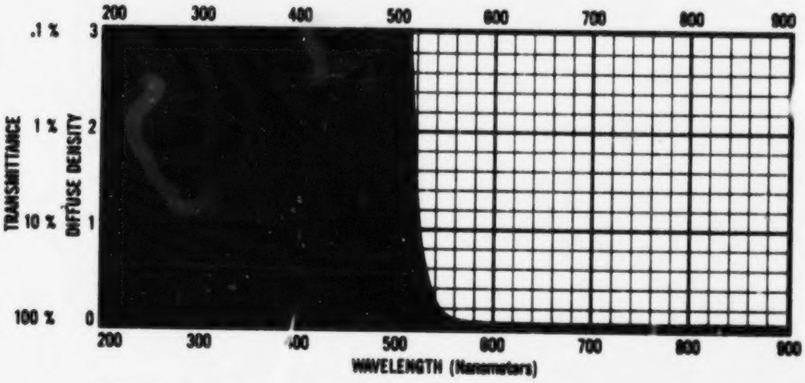


Sensitivity = Reciprocal of the exposure (ergs/cm²) required to produce a density of 1.0 above D min. Measurements were confined to the 400 to 900 nanometer region.

Spectral Dye Density Curves:

16

AAB



Orange. Permits greater overcorrection of sky than No. 15. Absorbs small amount of green.

APPENDIX B

DEVELOPMENT PROCESSES FOR BLACK-WHITE, COLOR RECONNAISSANCE FILMS

The film was processed in processors manufactured by Eastman Kodak Company. The infrared and true-color Ektachrome films were processed in the Ektachrome RT Processor, Model 1811, Type M, Federal Stock Number 6740-109-2987PK, Part Number 460250. This machine uses Kodak EA-5 chemicals. The temperature of the respective chemicals in the processor and the film process rate, in feet per minute, are the important parameters. Their values were specified as follows:

1)	Prehardner	115°F
2)	Neutralizer	115°F
3)	First Developer	115°F
4)	First Stop Bath	115°F
5)	Color Developer	120°F
6)	Second Stop Bath	120°F
7)	Bleach	125°F
8)	Fixer	120°F
9)	Stablizer	120°F

The film process rate was 9 feet per minute. The nine chemical baths, mentioned above, comprise the EA-5 process used for the color films. The temperature and pressure of the fresh water supplied to the processor was 120°F and 45 pounds per square inch minimum respectively. The fresh water is used to wash the film immediately before entering the dryers.

The black and white film 2403 was processed in a Kodak Versamat Model 11-CM processor using Kodak 641 chemicals. This process contains only two chemical baths which are the developer and fixer. During processing, these were maintained at 85°F with a film process rate of 12 feet per minute. Fresh water temperature was maintained at 85°F with a pressure greater than 45 pounds per square inch.

APPENDIX C

Focal Length, Angle of View, and the Effects of Focal Length and Altitude

The focal length of the aerial sensors affects the size (or scale) of the resulting imagery. At any given altitude, the image size changes in direct proportion to changes in focal length. Also for a given focal length, the image size is inversely proportional to the altitude.

The angle of view of a sensor is a function of the focal length and the image format size. The importance of the angle of view is its relationship to the amount of target area recorded in the imagery. Refer to the following diagrams: A. Focal length of a simple lens. B. Effect of focal length on scale and ground coverage. C. Effect of altitude on scale and ground coverage.

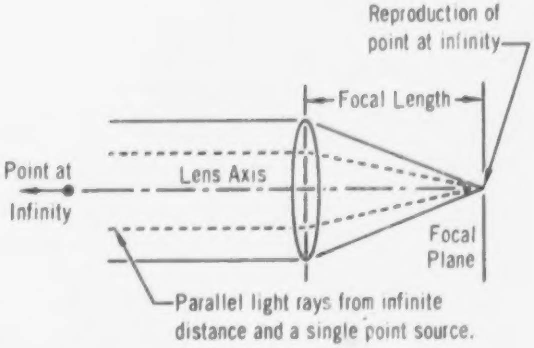

Reproduction of point at infinity
Focal Length
Point at Infinity
Lens Axis
Focal Plane
Parallel light rays from infinite distance and a single point source.

Diagram A. Focal Length of a Simple Lens

Focal length is the distance from the lens (A) to the film (B).

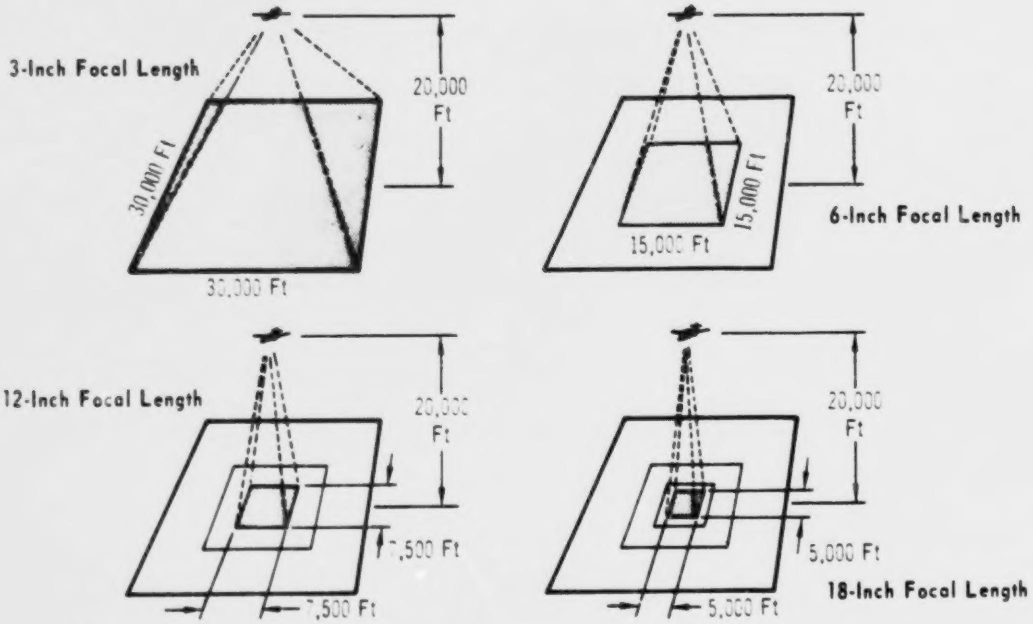

3-Inch Focal Length
20,000 Ft
30,000 Ft
30,000 Ft
20,000 Ft
15,000 Ft
15,000 Ft
6-Inch Focal Length
12-Inch Focal Length
20,000 Ft
7,500 Ft
7,500 Ft
20,000 Ft
5,000 Ft
5,000 Ft
18-Inch Focal Length

DIAGRAM B   Effect of Focal Length on Scale and Ground Coverage

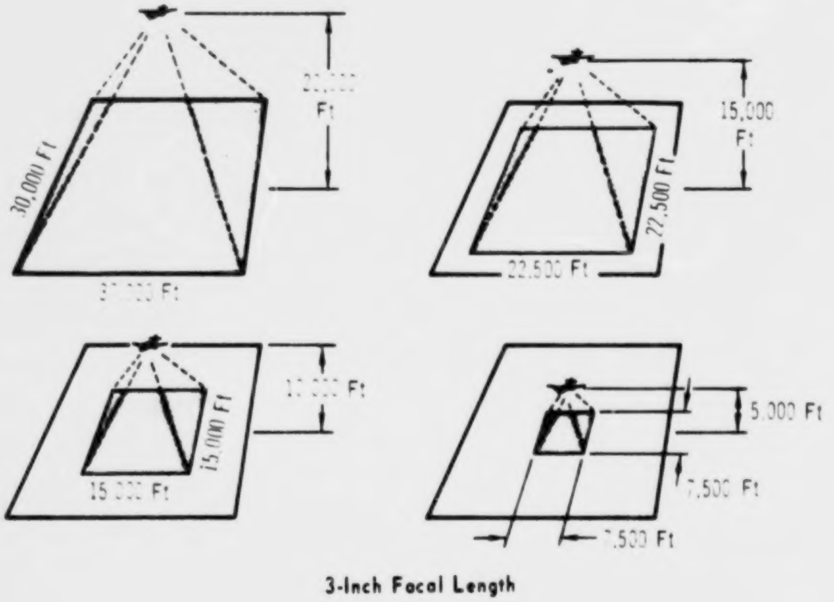

20,000 Ft
30,000 Ft
30,000 Ft
15,000 Ft
22,500 Ft
22,500 Ft
10,000 Ft
15,000 Ft
15,000 Ft
5,000 Ft
7,500 Ft
7,500 Ft
3-Inch Focal Length

DIAGRAM C   Effect of Altitude on Scale and Ground Coverage

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